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Yorktown Beach 2003-2005 with Hurricane Isabel Impacts



WILLIAM & MARY
VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE



January 2005

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A report obtained under contract with York County, Virginia

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January 2005

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1 INTRODUCTION

1.1 Site Information

The Yorktown Public Beach is located on the south side of the York River at Yorktown, Virginia (Figure 1). It is approximately 1,200 feet in length. Historically, the beach was a product of erosion of nearby sandy upland banks and the littoral transport system. Over the years, the beaches along the waterfront began to narrow as the natural sediment supply was depleted by hardening of the updrift shorelines and were easily overwashed in storms and had continually eroded.

Since 1978, various projects have taken place along Yorktown's shoreline in order to abate erosion, provide a recreational beach, and minimize damage to the upland during storms. Since 1994, seven breakwaters with beach fill have been installed along the shoreline. These structures have created a stable beach planform designed to withstand a 50-yr storm event. In September 2003, Hurricane Isabel impacted the Yorktown Beach and backshore. This event, with its high storm surge, caused considerable damage to the buildings along Water St. However, the rock breakwater units sustained no damage, and the beach required only the placement of 3,500 cubic yards of sand to be brought back to its pre-storm condition.

1.2 Hurricane Isabel

Hurricane Isabel made landfall along the southeast coast of North Carolina on September 18, 2003. At one time, the storm was a Category 5 on the Saffir-Simpson scale. It had been downgraded to a Category 2 before it made landfall. By the time it impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the "right-front" quadrant of the advancing hurricane, southeastern Virginia experienced east and east-southeast winds which are known to have the greatest potential to transport water into Chesapeake Bay and its Virginia tributaries. The hurricane impacted as far inland as Lake Erie.

The extent of coastal flooding during a storm depends largely on both the background astronomical tide and the surge generated by the storm's high winds and low atmospheric pressure. Together, surge and astronomical tide combine to form a "storm tide." Storm-tide flooding is maximized when the storm surge and a rising tide reach their peak at the same time. The hurricane of 1933, widely known as the "storm of the century" for Chesapeake Bay, generated a storm surge in Hampton Roads of 5.84 feet, more than a foot higher than the 4.76 ft storm surge recorded for Hurricane Isabel. Yet many long-time Tidewater residents say that the high-water marks left by Isabel equaled or exceeded those of the 1933 storm (Boon, 2003).

An analysis of sea-level records shows that Isabel's coastal flooding matched that of the August 1933 storm due to the long-term increase in sea level in Hampton Roads (Boon, 2003). Data from a tide monitoring station at Sewells Point show that sea level in Tidewater Virginia rose 1.35 feet between August 1933 and September 2003. Based on storm surge and astronomical tide, the 1933 hurricane storm surge exceeded Isabel's by more than a foot. Its surge also occurred at the beginning of spring tides while Isabel's surge occurred in the middle of

a neap tide. However, the increase in sea level at Hampton Roads in the seventy years between the two storms was enough to boost Isabel's storm tide to within an inch and a half of the level experienced during the 1933 storm (Boon, 2003).

Additional storm data was obtained by an Acoustic Doppler Current Profiler (ADCP) which was deployed in 28 ft of water offshore of VIMS at Gloucester Point. The instrument provided a quantitative record of the hurricane's impact on lower Chesapeake Bay. Data from the ADCP showed that Isabel created a 7-foot storm tide topped by 6-foot waves. At the height of the storm, wave crests were passing over the instrument once every 5 seconds, and the storm was forcing the entire flow of the York River upstream at a rate of 2 knots. Because Isabel was so large, its winds, waves, and surge effected the Bay for an abnormally long time. The ADCP data showed that storm conditions persisted in the Bay for nearly 12 hours and that wave-driven currents were strong enough to mobilize bottom sediments even at the instrument's depth, increasing water turbidity by a factor of two to three compared to fair-weather conditions (VIMS, 2003).

Around the Bay, similar impacts were recorded by tide gages. However, the gage at Gloucester Point across the river from Yorktown was destroyed during the storm before the peak water level was reached ([Figure 2](#)). This tide gage stopped recording at 8.5 ft MLLW during the storm. Maximum measured stillwater level across the river at Yorktown was 8.6 ft MLLW with the trash line indicating the water plus waves was at 12.5 ft MLLW. That is a surge above the mean range (2.4 ft) of 6 ft with additional 4 ft waves. Weather data provided by instruments atop VIMS' Byrd Hall showed that maximum sustained winds on the campus reached 65 mph, with 90-mph gusts. The barometer bottomed out at 29.2 inches, with a rainfall accumulation of about 2.2 inches (VIMS, 2003).

2 METHODS

2.1 Site Surveying

Shoreline Studies personnel from VIMS began monitoring the beach at Yorktown in the spring of 1985. Due to a storm event, the baseline was reset in 1986 and slightly altered in September 1993 ([Figure 3](#)). In September 1994, two additional profile lines were added, 6.5 and 8.5. During construction of the downriver breakwaters in Phase II, VIMS personnel added six new profile lines (profiles 15-20). The baseline for profiles 5 to 11 was re-established on 4 May 2000 after the completion of the walkway. For additional information, see Milligan *et al.* (1996). Beginning in 2003, new methodologies were established for surveying the beach. The Trimble 4700 Real-Time Kinematic Global Positioning System (RTK-GPS) was used to set site control and acquire beach and shore data. The 4700 receiver utilizes dual-frequency, real-time technology to obtain centimeter accuracy in surveying applications. In addition, a Trimble 5600 Robotic Total Station was used to acquire data in the nearshore. The combination of these new instruments allows for a more detailed mapping of the beach and nearshore in a shorter amount of time.

Three shoreline and nearshore surveys were performed at Yorktown during 2003. The pre-hurricane survey was performed in June 2003; the post-hurricane survey occurred on 25 September 2003; and a recovery survey was performed on 18 December 2003. The beach was also surveyed on 27 July 2004 and 5 Jan 2005. Due to construction on the upriver portion of the site, profiles north of Profile 4 could not be surveyed. The planform surveys are shown in [Appendix A](#).

The RTK-GPS base station benchmark was pre-set with a 2-hour occupation. These data were processed through the National Geodetic Survey's On-line Positioning User Service (OPUS). All the survey data were based on this benchmark. In addition, 3-minute occupations were taken at previously- established benchmarks in order to tie newer data to the older data as well as determine survey error. The data is presented with a horizontal datum is UTM, Zone 18 North, NAD83, international feet. The vertical datum is feet MLLW, geoid99, as determined from nearby benchmarks publishing both NAVD88 and MLLW for the 1983-2001 tidal epoch.

Generally, the surveys included the following elements:

1. Dimensions of the project structures including breakwaters and revetments;
2. Mean High Water (MHW) and Mean Lower Low Water (MLLW); survey extends to approx. the -4 ft MLLW contour (Tidal Epoch 1983-2001).
3. The post-storm survey included measurements of still-water level on a Water St. restaurant as well as trash lines along the upland site where visible.

2.2 Aerial Photo Geo-Referencing and Mosaicking

Recent color aerial photography was acquired by Shoreline Studies Program to help estimate, observe, and analyze shoreline changes before and after Hurricane Isabel impacted the breakwater sites on September 18, 2003. The images were scanned as tiff files at 600 dpi. ESRI

ArcMap GIS (www.esri.com) software was used to georeference the images for Yorktown. The reference mosaic, the 2002 Digital Orthophotos from the Virginia Base Mapping Program (VBMP), is divided into a series of orthophoto tiles and is stored in a Virginia south, state plane projection, in feet. The aerial photo tiles from VBMP for each site were mosaicked and re-projected to a UTM zone 18 North, NAD83 projection, in meters.

Rectifying requires the use of ground control points to register the aerial photography to the reference images. Ground control points are points that mark features found in common on both the reference images and on the aerial photographs that are being georeferenced. Control points were distributed evenly to maintain an accurate registration without excessive amounts of warp and twist in the images. In addition, where possible, enough control points were placed within the area of interest, the shoreline and the breakwaters, to ensure accurate registration in these key areas. This can be challenging in areas with little development. Good examples of control points are permanent features such as manmade objects and stable natural landmarks. The standard in this project was to achieve a root mean square (RMS) error under six for each aerial photo.

Georeferencing was done by using the Georeferencing Tool in ArcMap. First the reference image and the scanned aerial photograph are roughly aligned so that common points can be identified. Then, with the aid of the Georeferencing tool, ground control points are added until the overall RMS error is less than six and the location of the aerial photograph closely matches the location of the reference image. When an acceptable correspondence is achieved, the aerial photograph is saved as a rectified image. All the rectified images were then mosaicked using the mosaic tool in ERDAS Imagine (<http://www.gis.leica-geosystems.com/Products/Imagine/>).

3 RESULTS

3.1 Site Survey

The plots of each profile and all dates are shown in [Appendix B](#). Selected typical profiles before and after Hurricane Isabel impacted the shore show cross-sectional changes as a basic cut and fill in the embayments ([Figure 4](#)). Shearing occurred across the top of the tombolos behind each breakwater. Some sand was lost to the offshore after the storm but the County filled the beach to its pre-storm profile shortly after the hurricane. The cross-sectional profiles were analyzed in sections including the volume change above MHW (defined as +2.5 ft MLLW), volume between MHW and MLLW, and volume between MLLW and -4 ft MLLW ([Table 1](#)). Volume calculations indicate that all of the sand loss occurred above MHW during the storm. In addition, much of the sand was deposited in the nearshore since about 600 cy could be accounted for in that region. When the recovery beach fill was placed, most sand also was placed above MHW with little being deposited on the beach face. In fact, some of the sand in the nearshore was lost as the sand deposited by Isabel moved. The post Isabel sand replacement is shown for selected profiles in [Figure 5](#). The sand had begun to equilibrate by July 2004 and continued into 2005 as sand shifts around each embayment and behind the breakwaters ([Figure 6](#)). The loss of sand above MHW between December 2003 and July 2004 is the resulting movement of sand from areas that may have been “over-filled” during the overall nourishment of the beach after the storm.

Distance to MHW from the baseline is commonly plotted to show the movement of the subaerial beach ([Figure 7](#)). In general, the position of MHW receded except for a few locations where a quantity of sand was eroded from the upper beach and deposited on the lower beach. The movement riverward of the position of MHW in December 2003 is due to the beach renourishment. Since that time the beach has been equilibrating as the sand shifts around the embayments.

Table 1. Net volume change for profiles 2-19.

Time Period	Volume Change (cubic yards)		
	Above MHW	Between MHW & MLLW	Between MLLW and -4 MLLW
Pre to Post Isabel June-September 2003	-790	0	+680
Post Isabel to Recovery September-December 2003	700	160	-80
December 2003-July 2004	-310	-90	-220

3.2 Isabel Impacts Shown by Photography

Pre- and post-Isabel low level aerial imagery show a narrowing of each tombolo and a landward shift of sand behind each breakwater unit (Figure 8). The shoreline position in the two middle and largest embayments (Bays C and D) showed only slight changes after the storm. Post-storm recovery about one year later shows shore planforms to have returned to near their pre-storm position. A noticeable shore advance is seen in Bay C.

Historically, during storms, sand was carried into the adjacent street, but recent granite block "backstops" helped reduce this tendency during Isabel. These blocks measuring about 1 ft square, 5 feet long, and weighing about 1 ton were easily shifted around by the storm waves. Several areas of scour occurred along the backshore/sidewalk/road juncture exposing the underlying stone revetment (Figure 9). Post-storm clean up and added fill restored the public beach to use by late October 2003. The businesses along the waterfront were severely impacted by the high water, and it took several months for their rehabilitation, but they are presently operating. Figure 10 shows a low backshore along Water Street in Yorktown as well as the storm wrack lines which are the floating debris accumulated at the limit of high water. At Colonial National Historical Park, just downriver from Yorktown, small rocks from the revetment along the shoreline were scattered on the road, and the adjacent upland bank was severely scarped.

4 CONCLUSIONS

The waterfront at Yorktown was severely impacted by Hurricane Isabel. The low backshore and adjacent low bank allowed the storm surge to flood the restaurants along Water Street. However, the wave action was significantly reduced by the public beach's breakwater system. This system experienced sand losses and local scour but maintained its overall integrity with no damage to the breakwater units themselves. This system performed above expectations since it was designed for a 50-year event and sustained what many consider a 100- year event in this part of Bay.

5 REFERENCES

- Boon, J., 2003. The Three Faces of Isabel: Storm Surge, Storm Tide, and Sea Level Rise. Informal paper. <http://www.vims.edu/physical/research/isabel/>.
- Milligan, D.A., C.S. Hardaway, Jr., and G.R. Thomas, 1996. Public Beach Assessment Report, Yorktown Public Beach, Yorktown, Virginia. Technical Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.
- VIMS, 2003. VIMS scientists quantify Isabel's impacts on the Bay. Press Release. http://www.vims.edu/newsmedia/press_release/isabel.html



Figure 1. Location of Yorktown Public Beach.

Gloucester Point

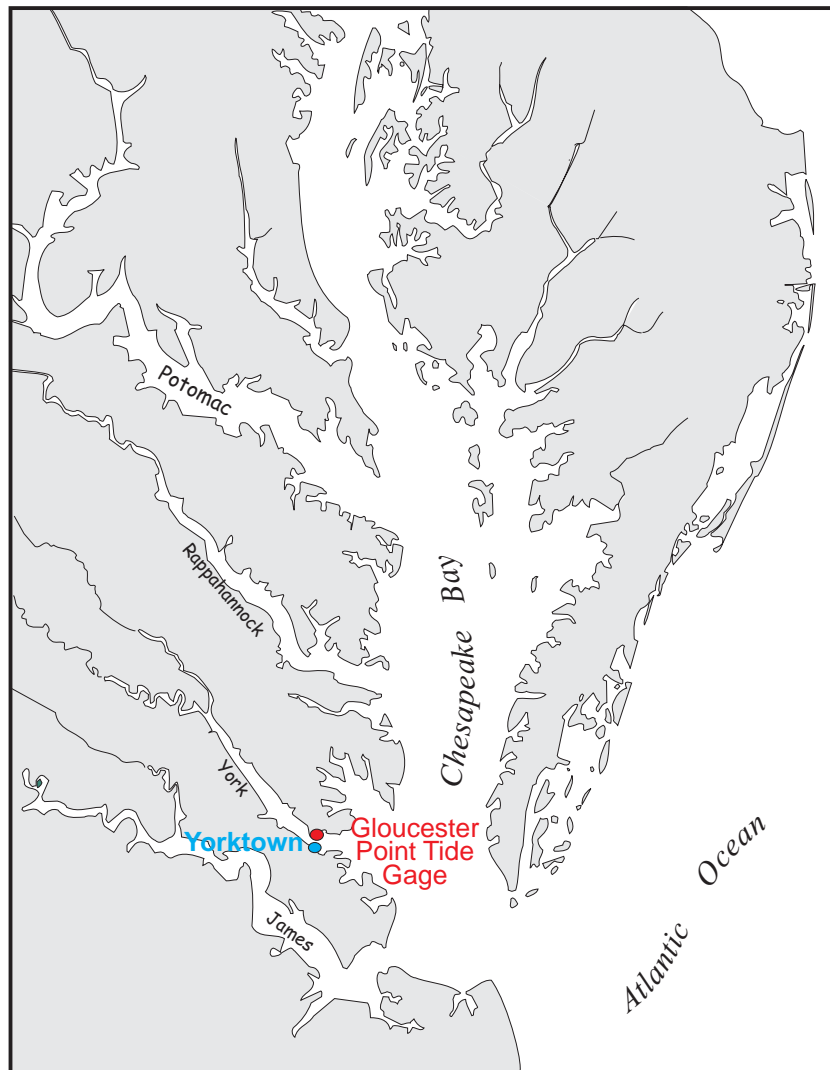
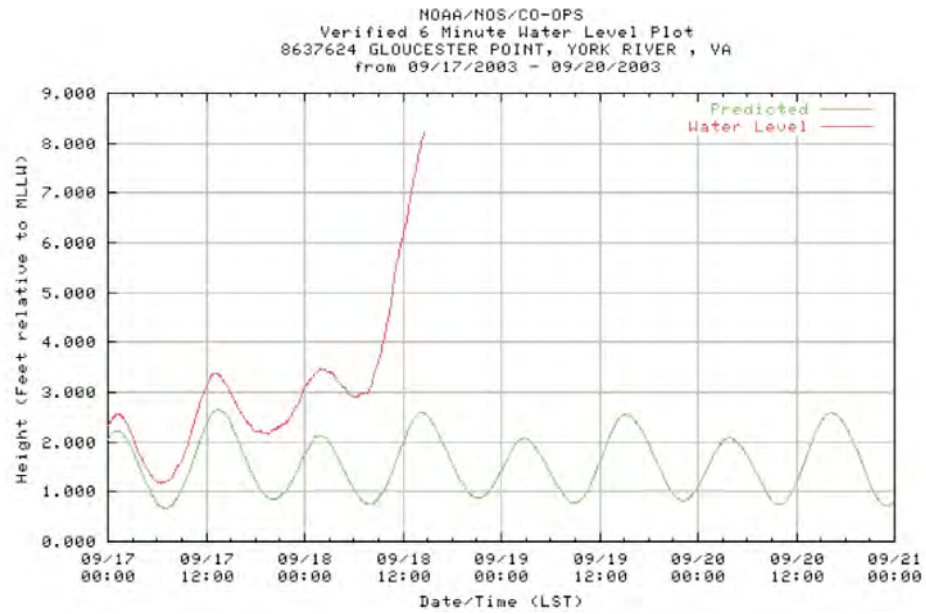


Figure 2. Location of Yorktown in relation to the Gloucester Point Tide gage and the gage's tide record during Hurricane Isabel.

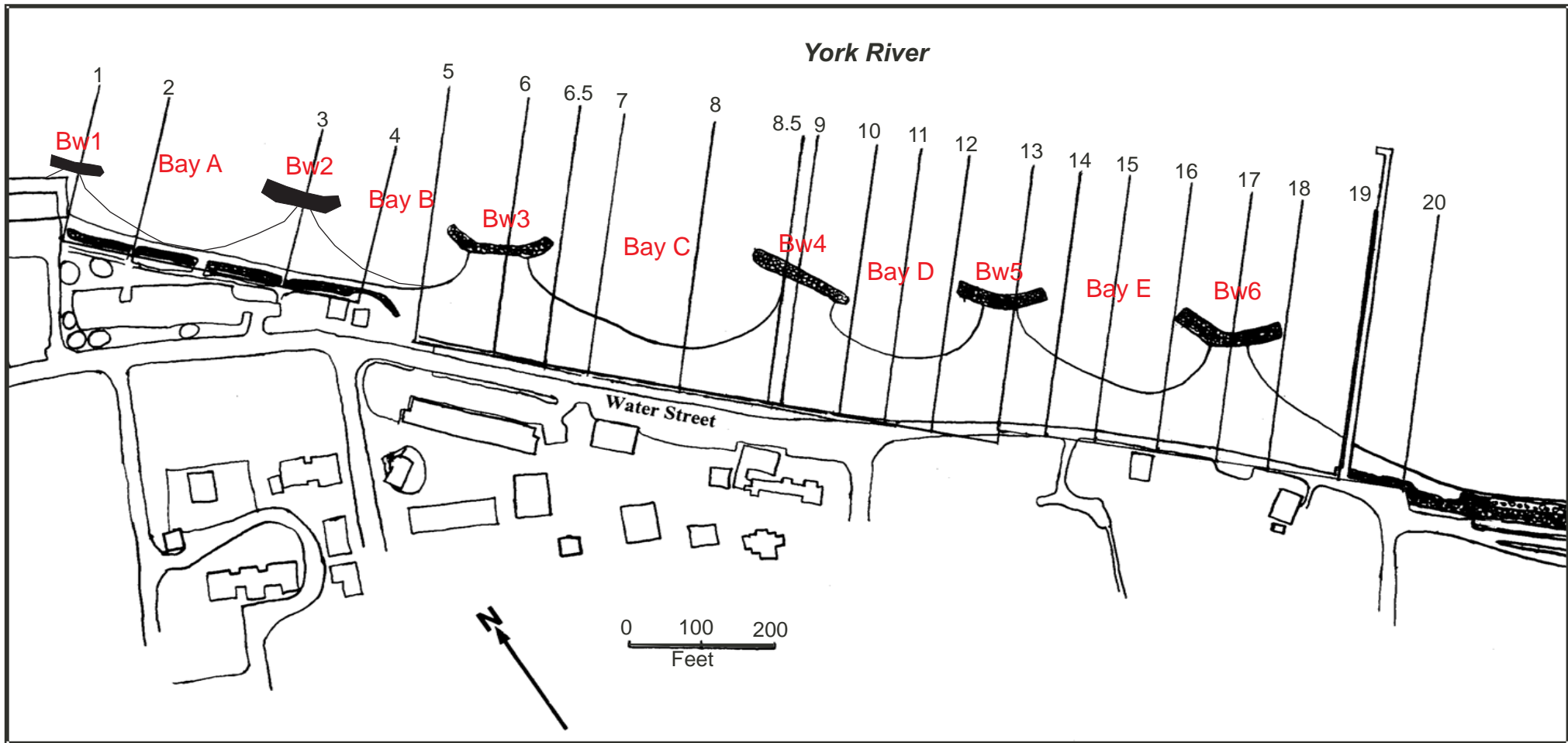


Figure 3. Yorktown Public Beach survey baseline.

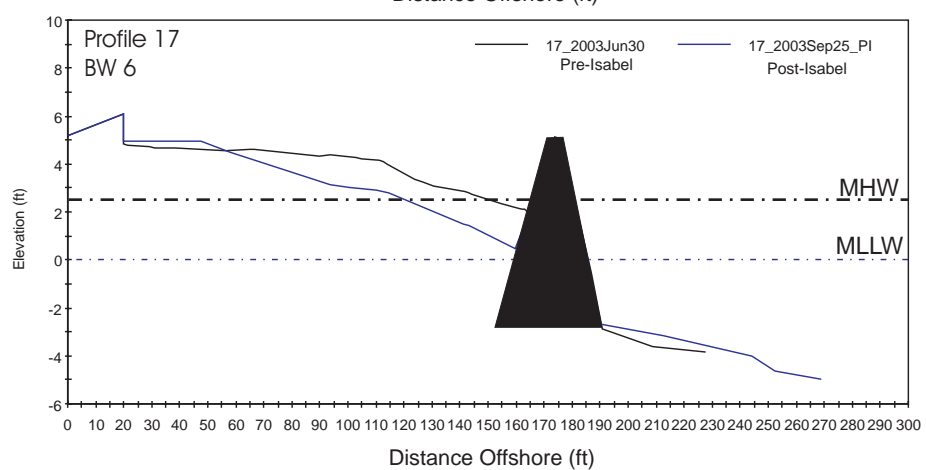
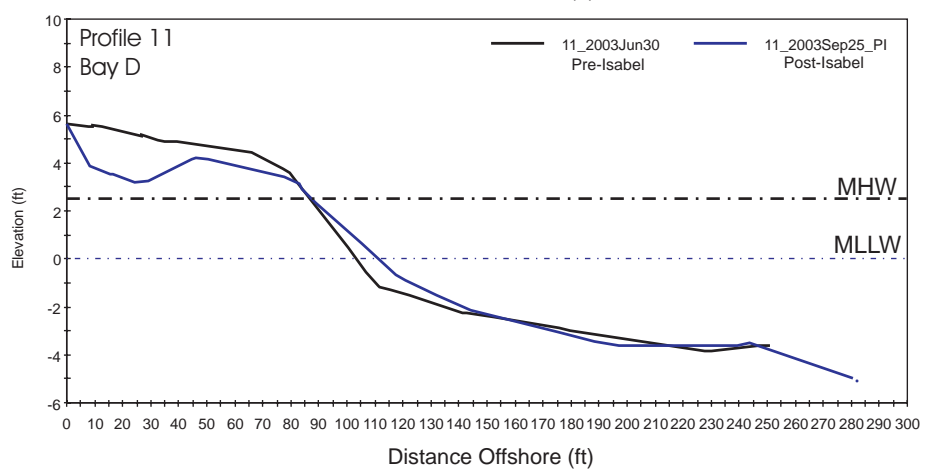
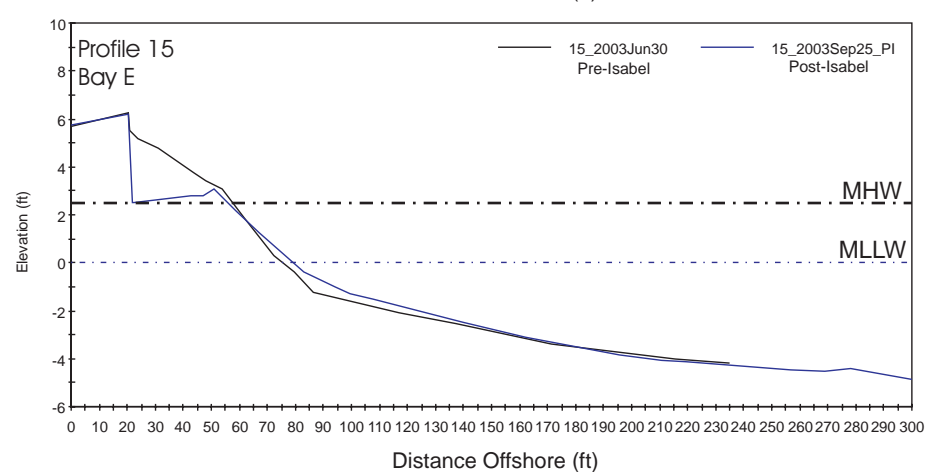
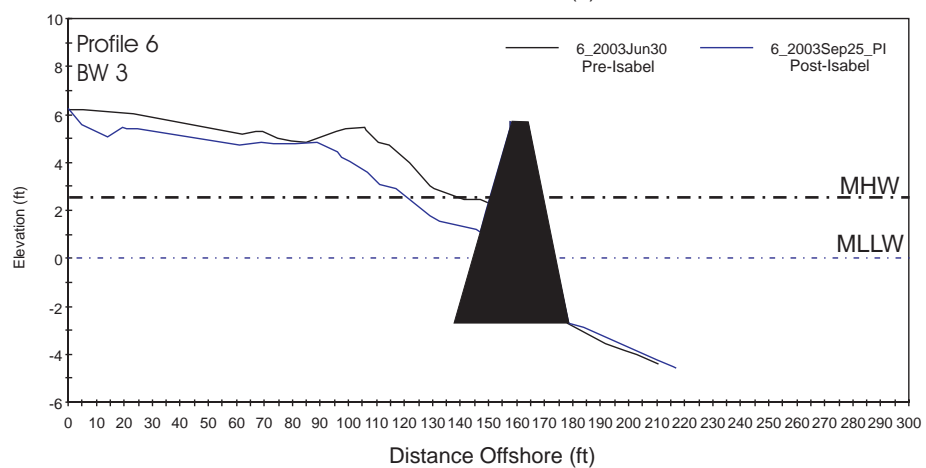
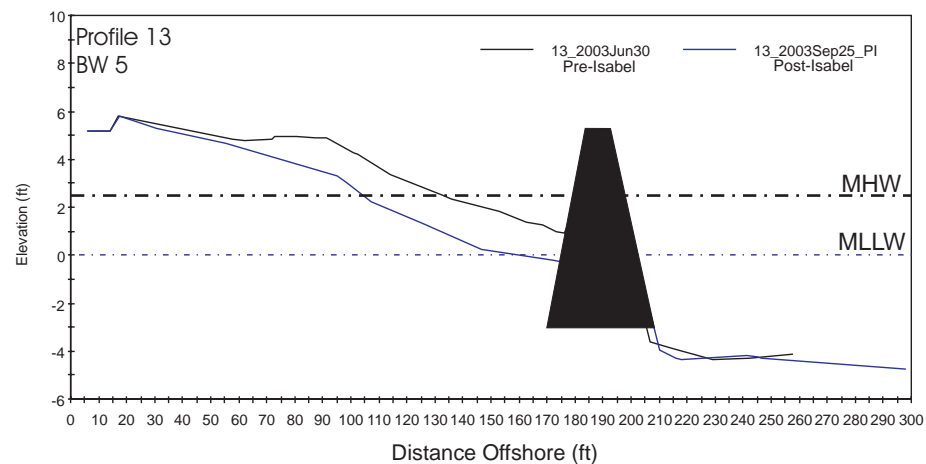
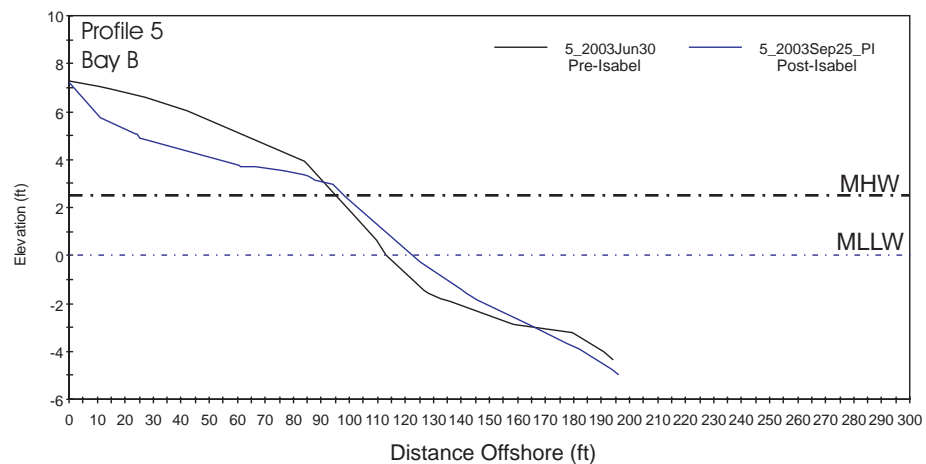


Figure 4. Selected pre- to post-Hurricane Isabel profile plots.

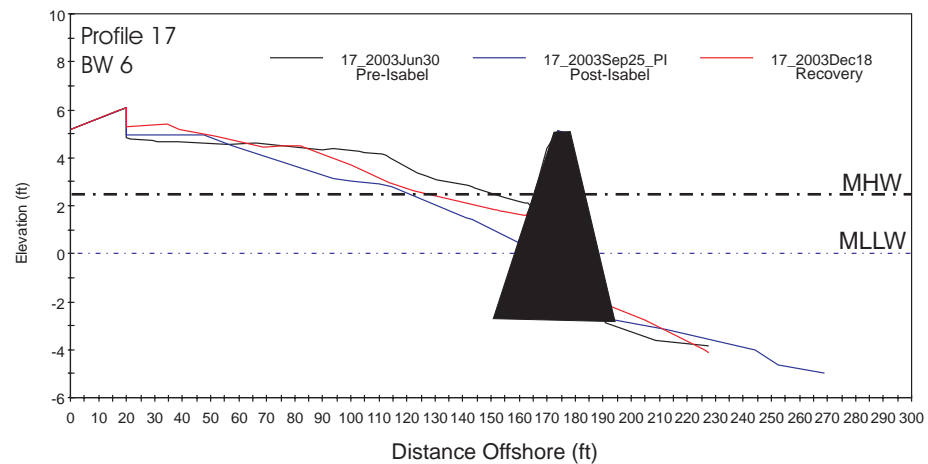
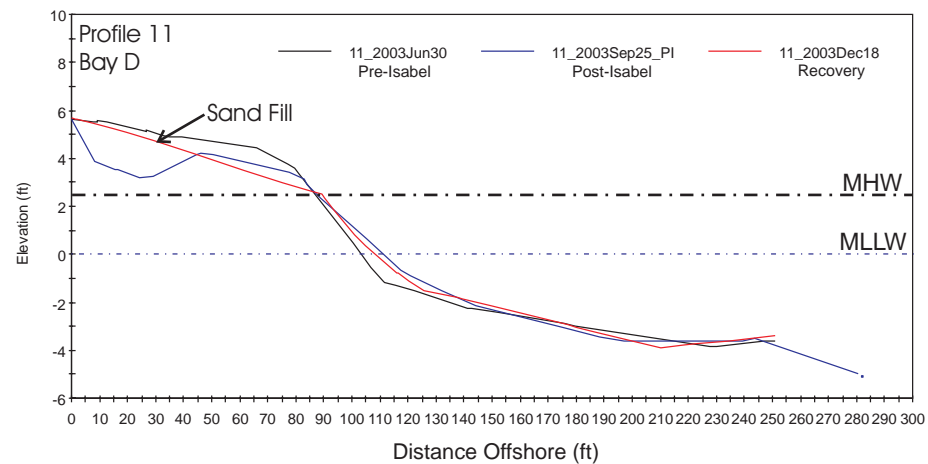
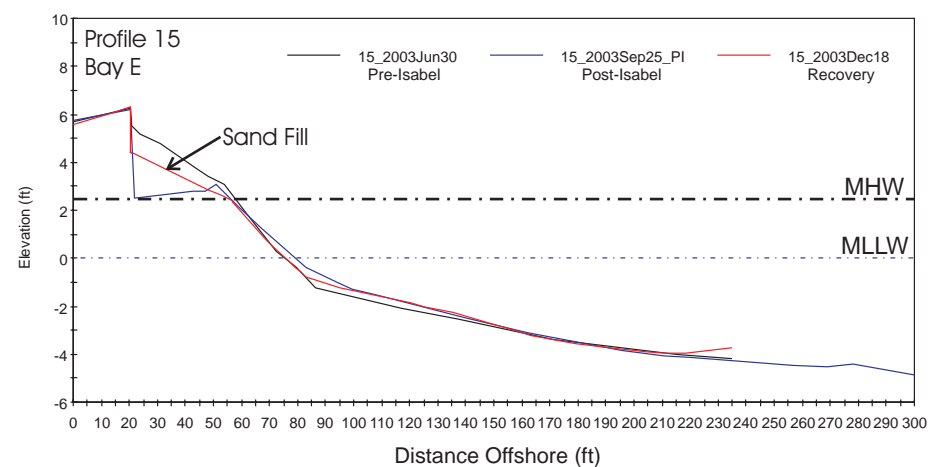
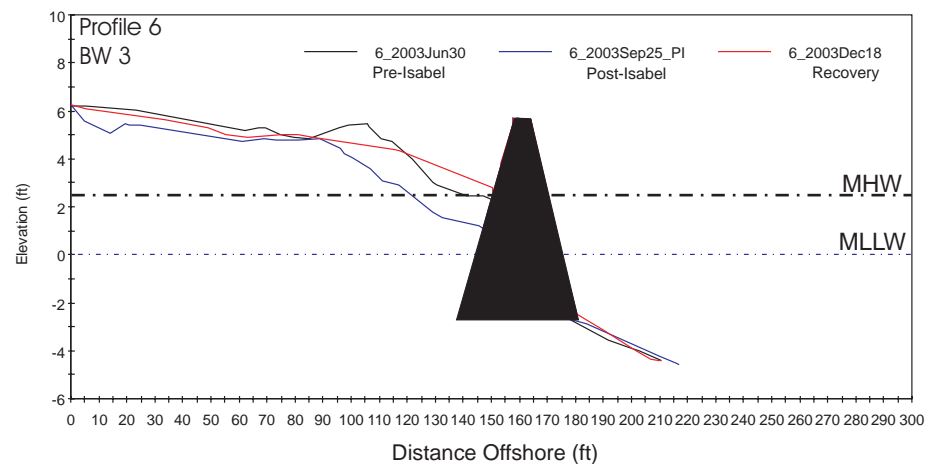
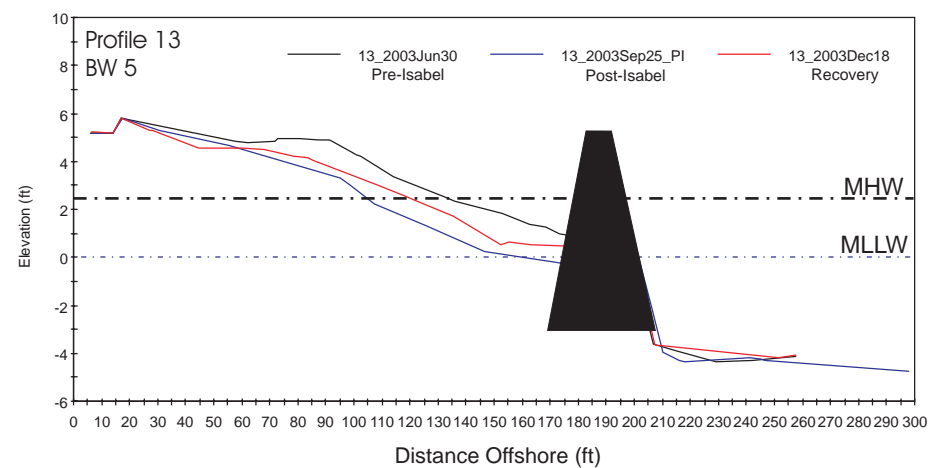
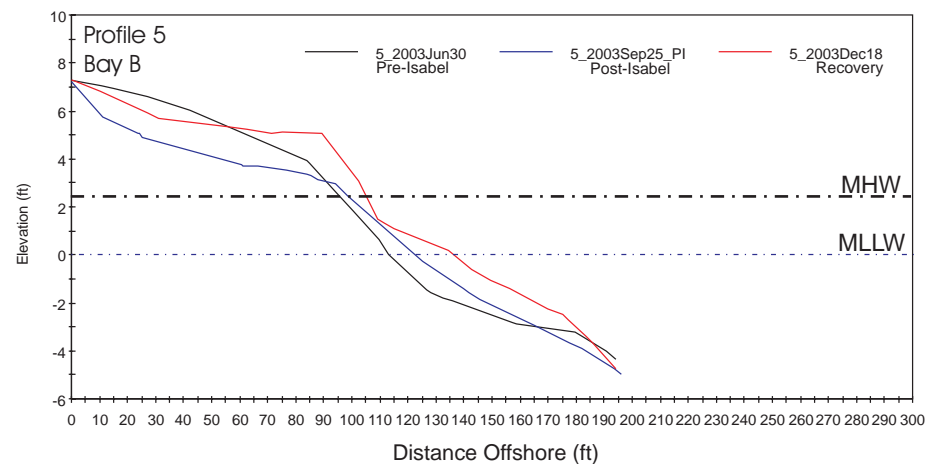
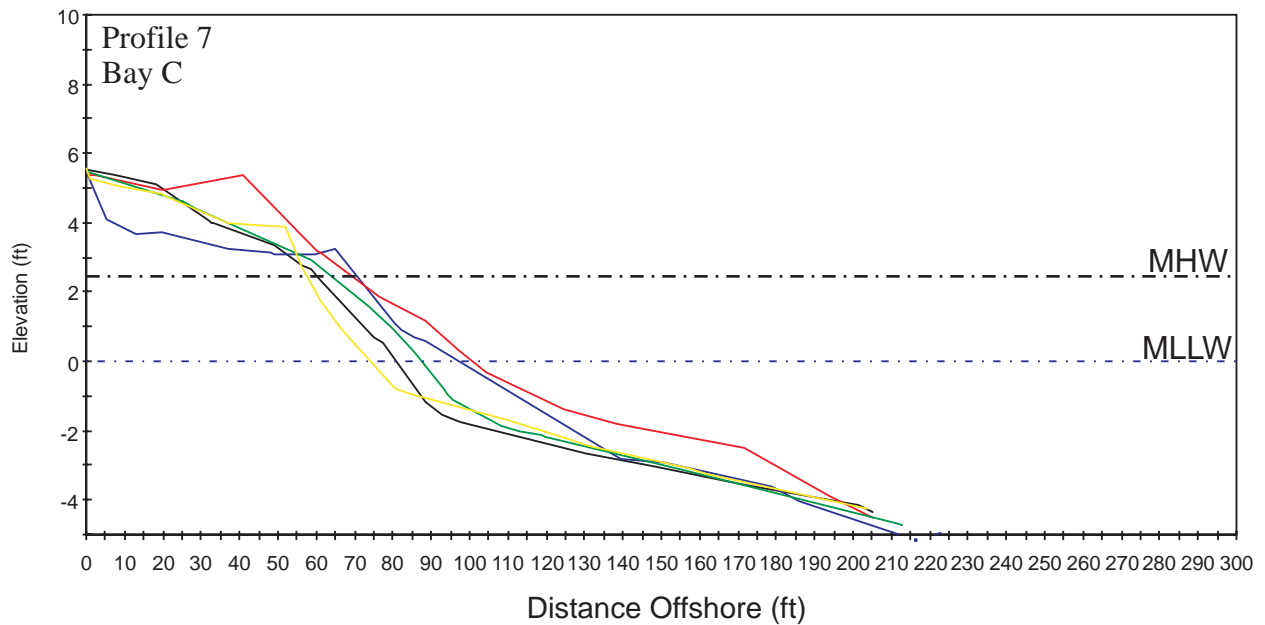
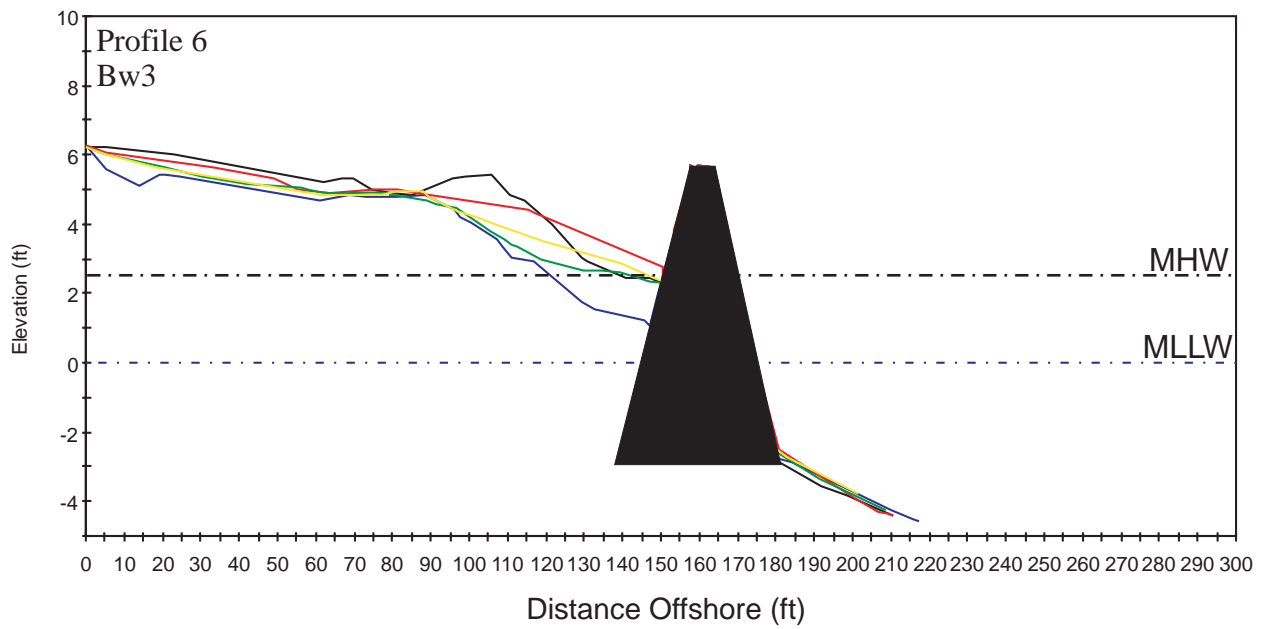
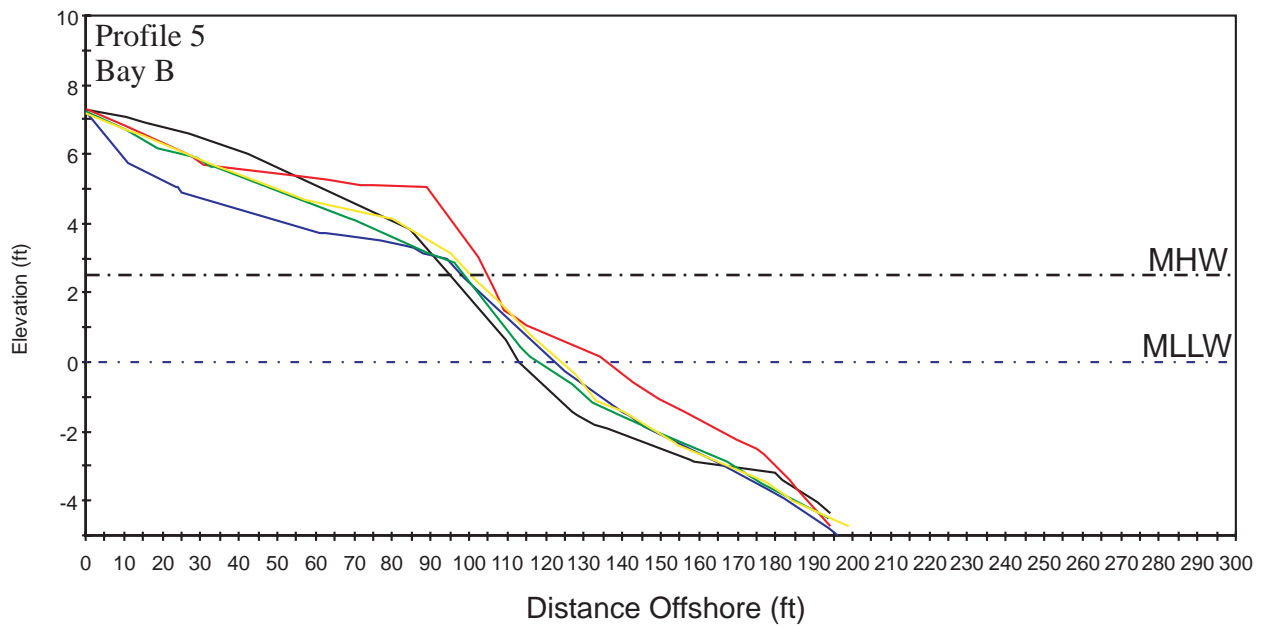


Figure 5. Selected pre- to post-Hurricane Isabel and recovery profile plots.



— 2003Jun30 — 2003Sep25_PI — 2003Dec18 — 2004Jul27 — 2005Jan5

Figure 6. Selected plots of all profile dates.

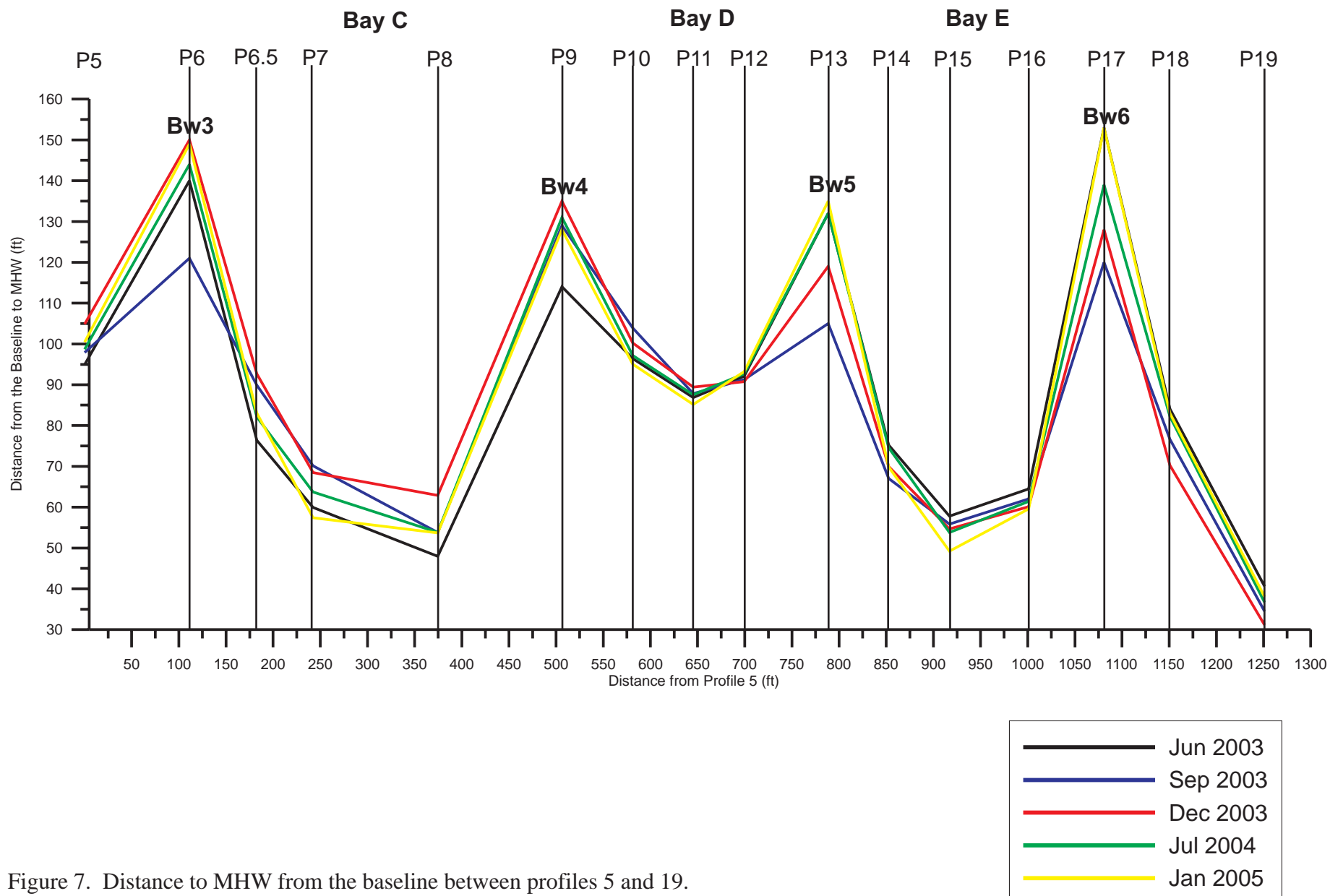
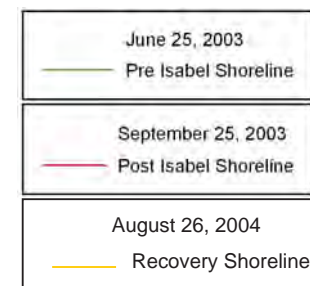


Figure 7. Distance to MHW from the baseline between profiles 5 and 19.



Yorktown



Mean Tide Range=2.5 ft

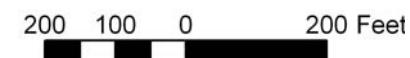


Figure 8. Yorktown low-level pre- and post-Hurricane Isabel and recovery ortho-rectified aerial photos.



View along the downriver portion of Water Street



View along the upriver portion of Water Street at the main recreational area



Figure 9. Yorktown ground photos before and after Hurricane Isabel.



A
Pre-storm
low backshore



B
Post-storm
wrack line



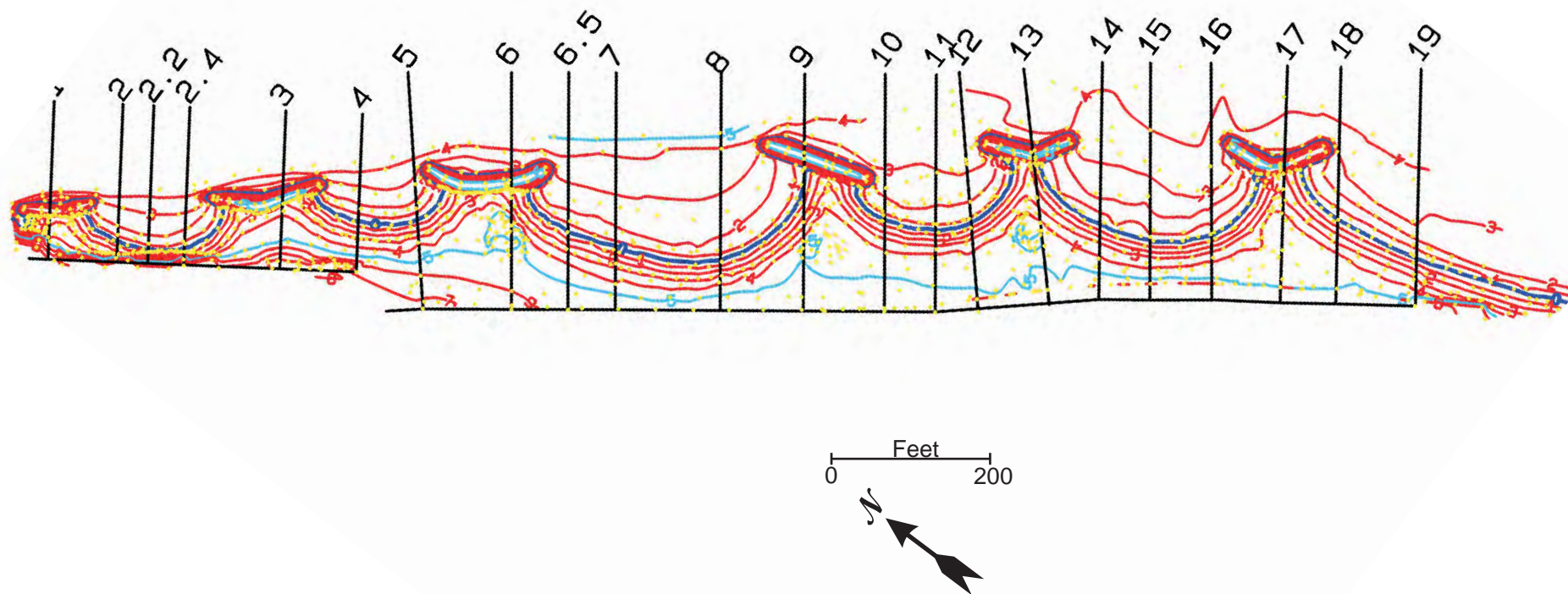
C
Post-storm
wrack line
downriver

Figure 10. Yorktown A) backshore and B) post-storm wrack line and C) adjacent shore impacts.

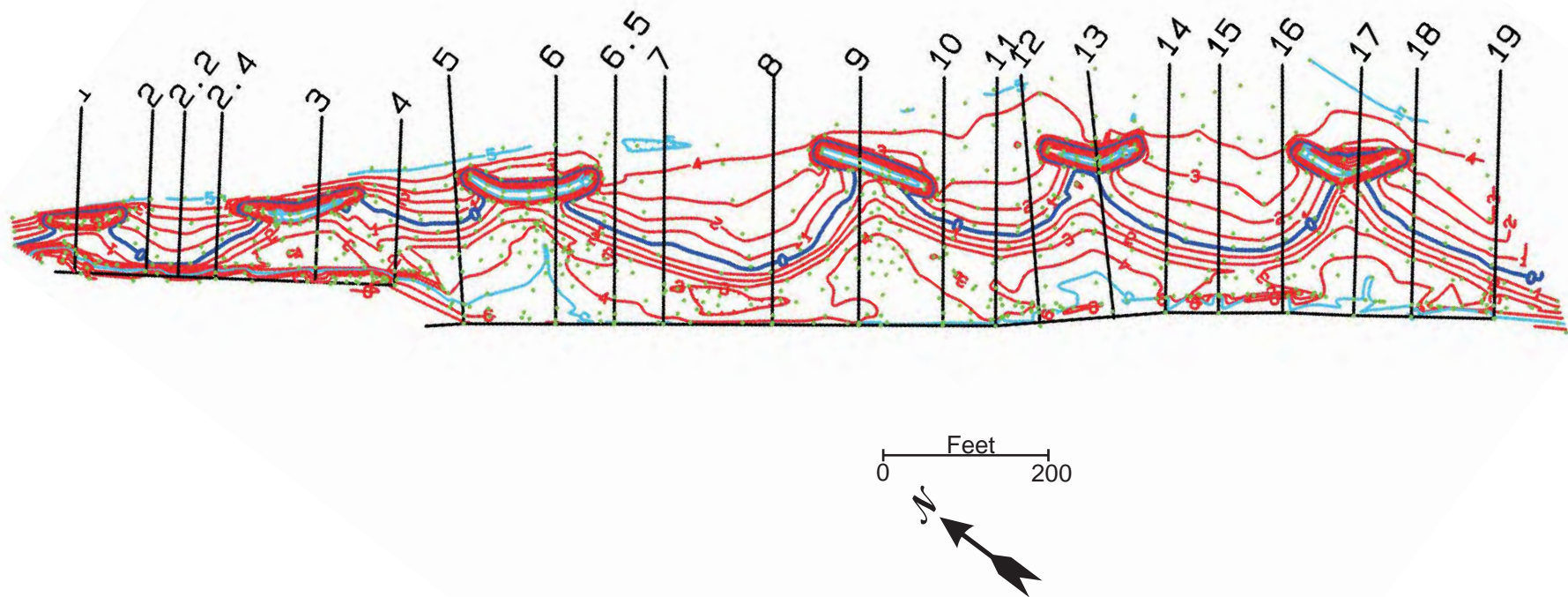
APPENDIX A

Yorktown Beach Planform Survey Plots

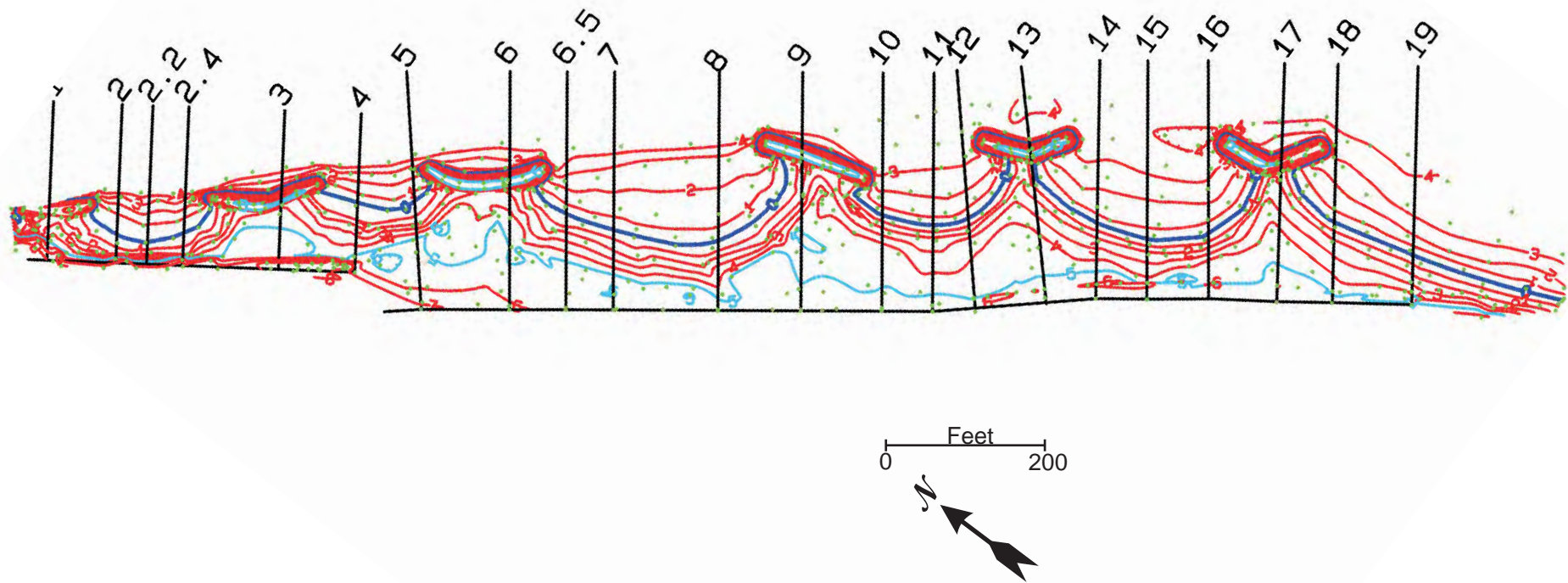
2003-2005



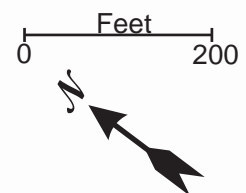
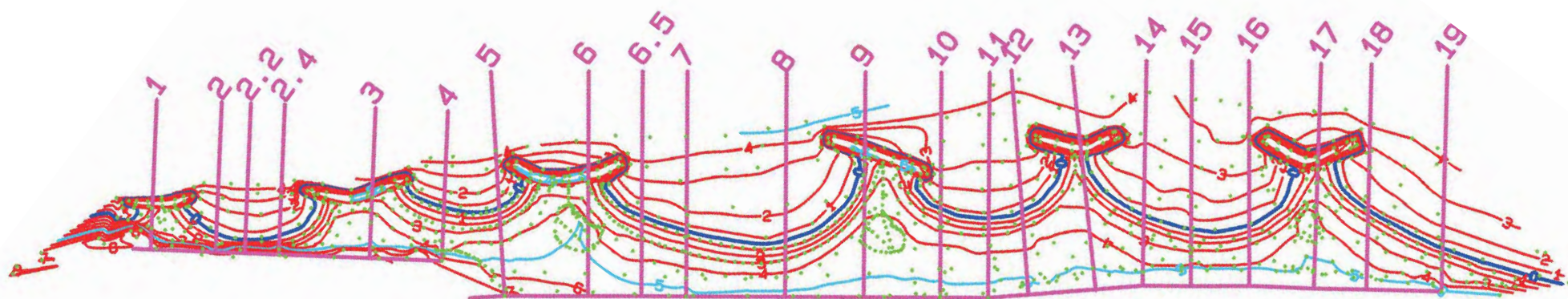
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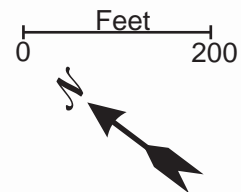
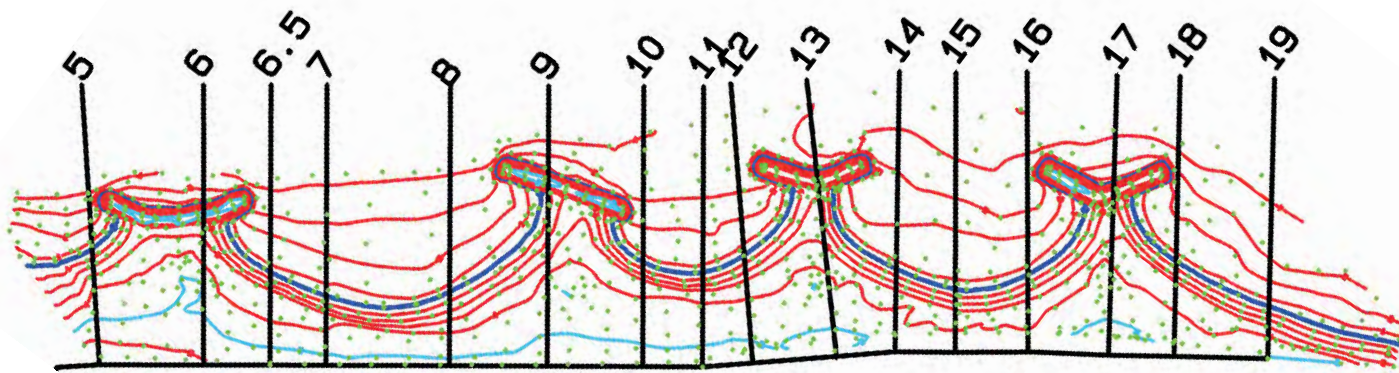
Yorktown Public Beach Survey 25 September 2003 - Post Hurricane Isabel



Yorktown Public Beach Survey 18 December 2003



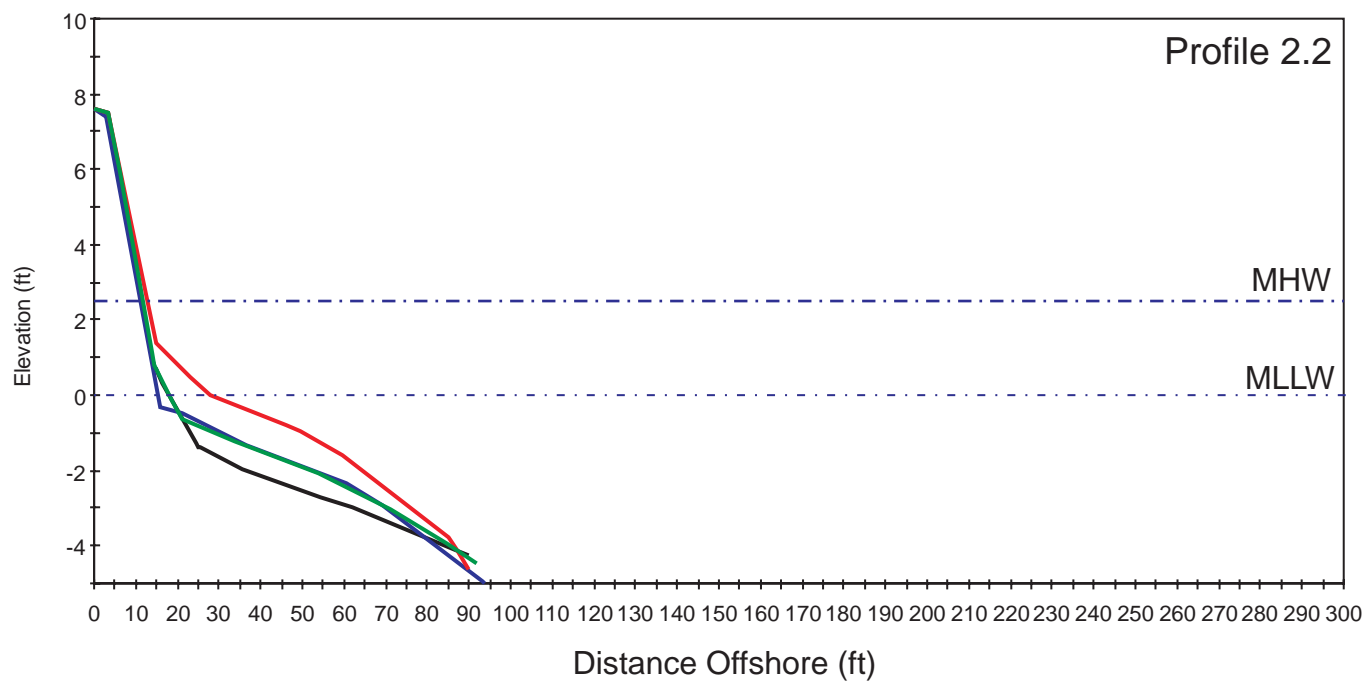
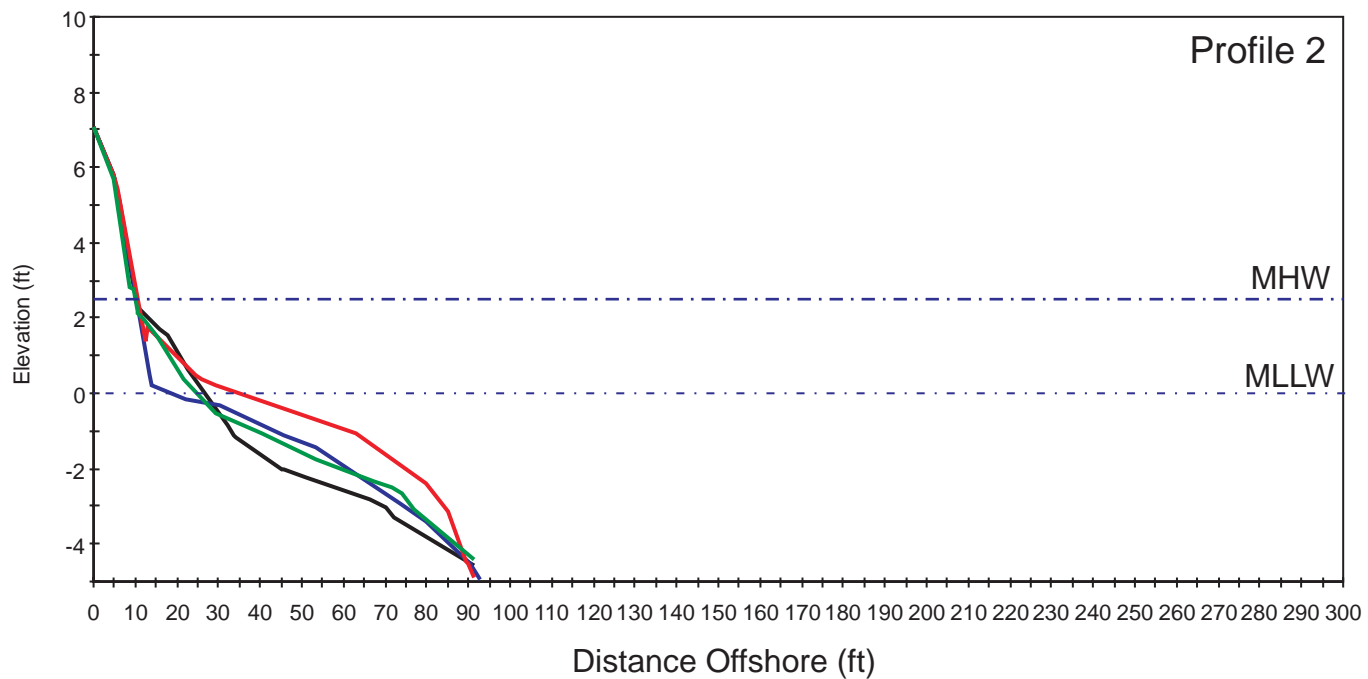
Yorktown Public Beach Survey 27 July 2004



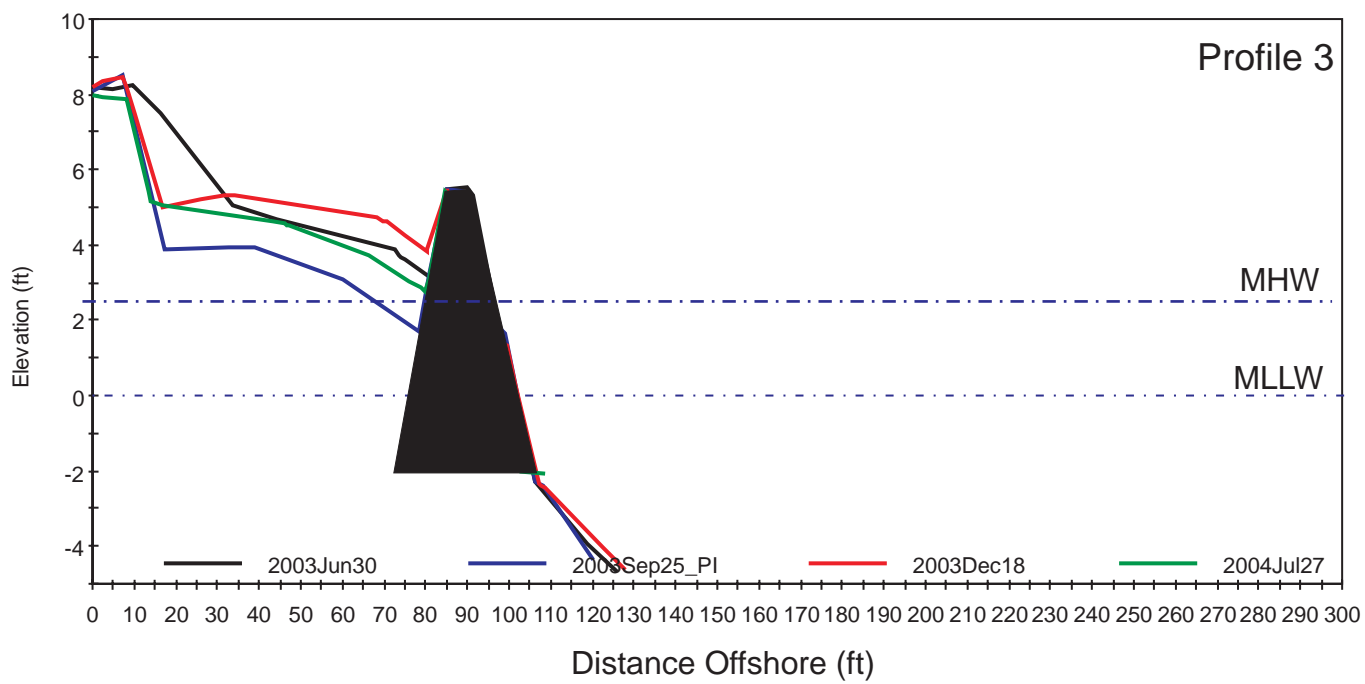
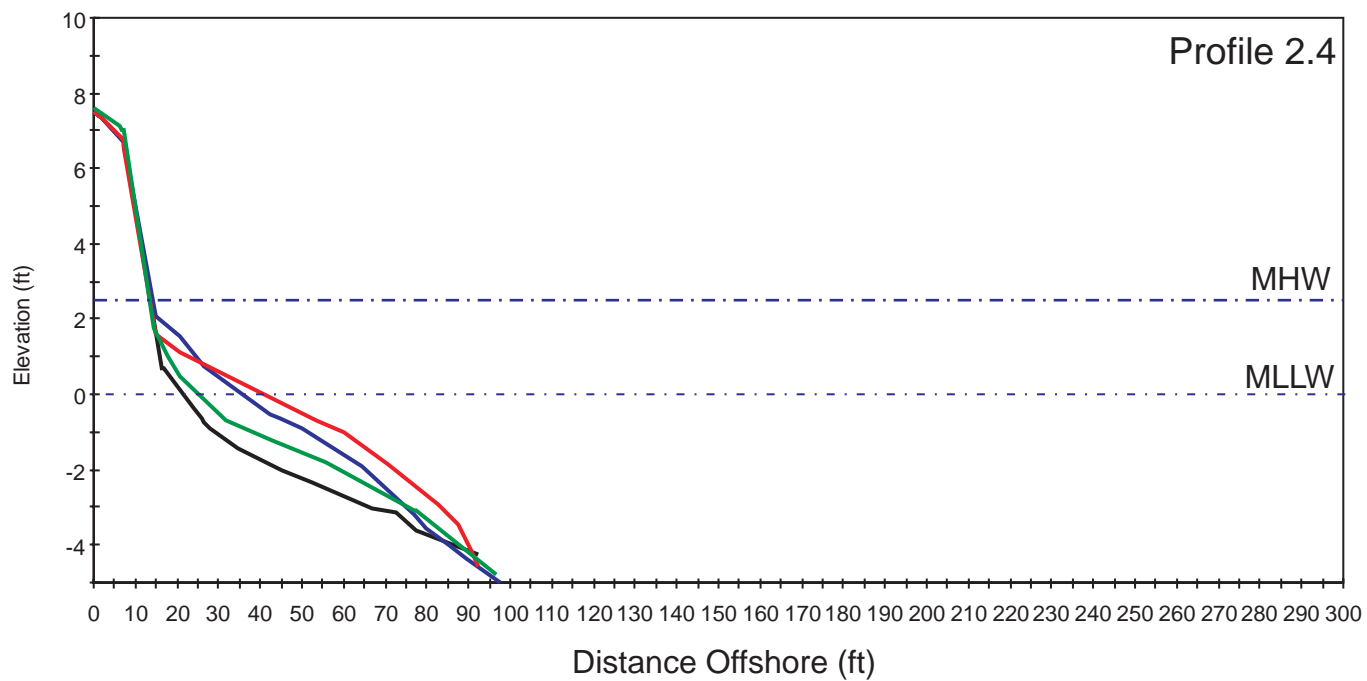
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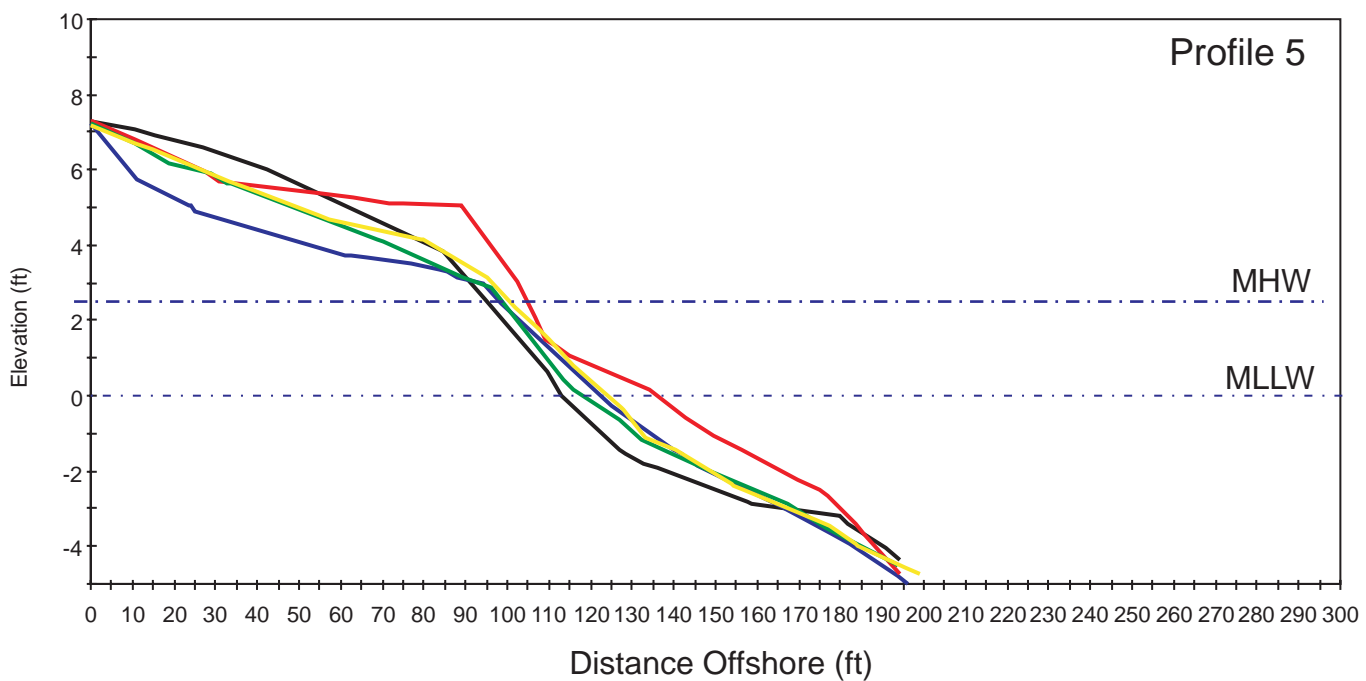
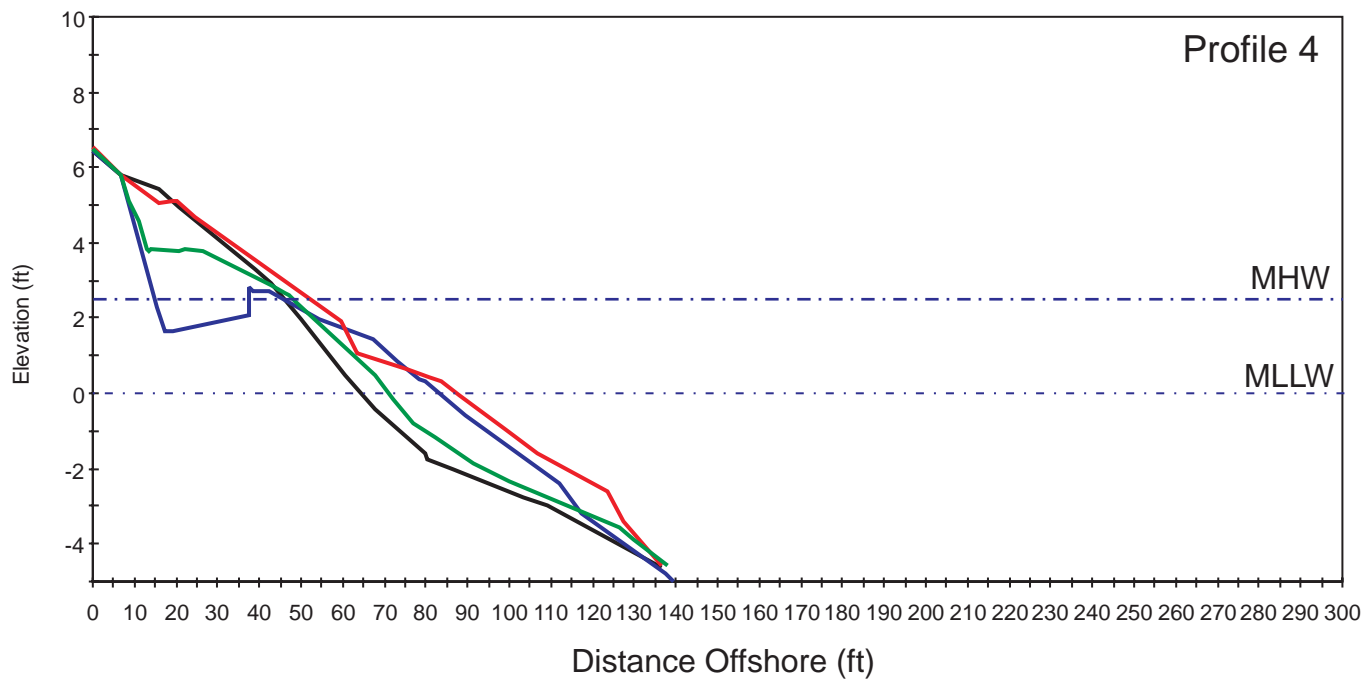
APPENDIX B

Yorktown Beach Cross-Sectional Profile Plots
2003-2005

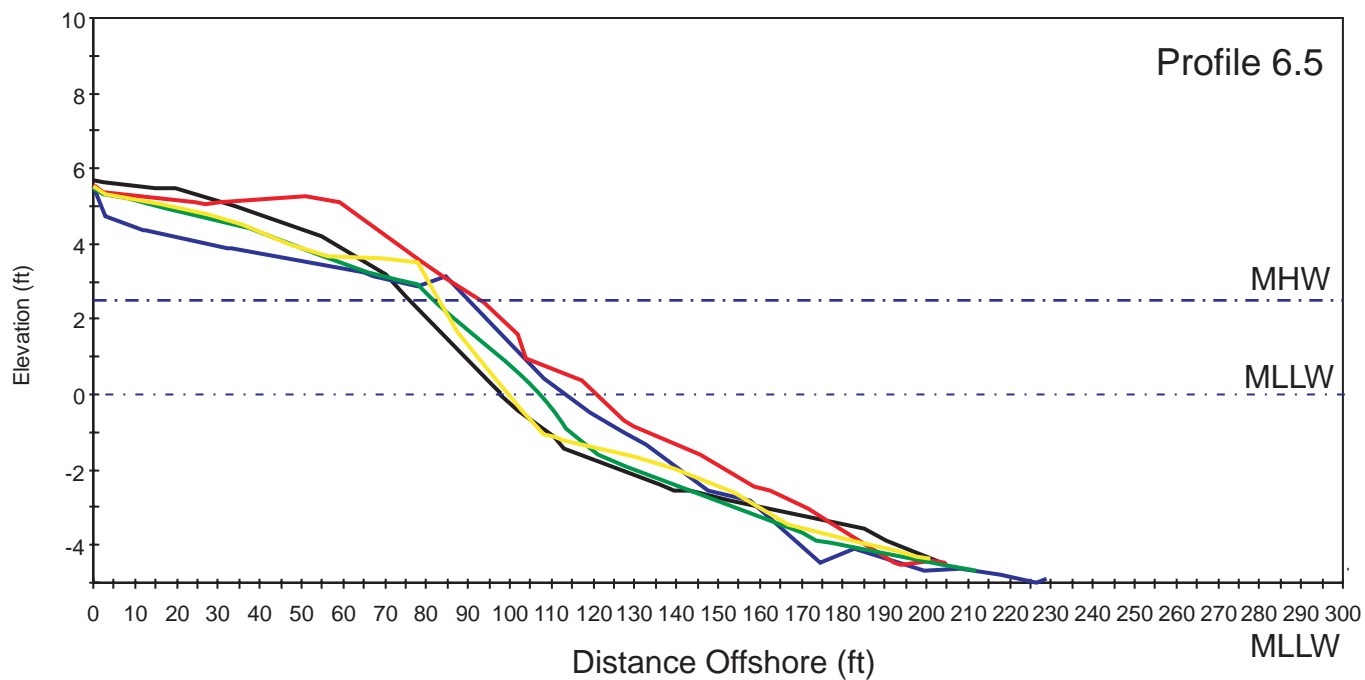
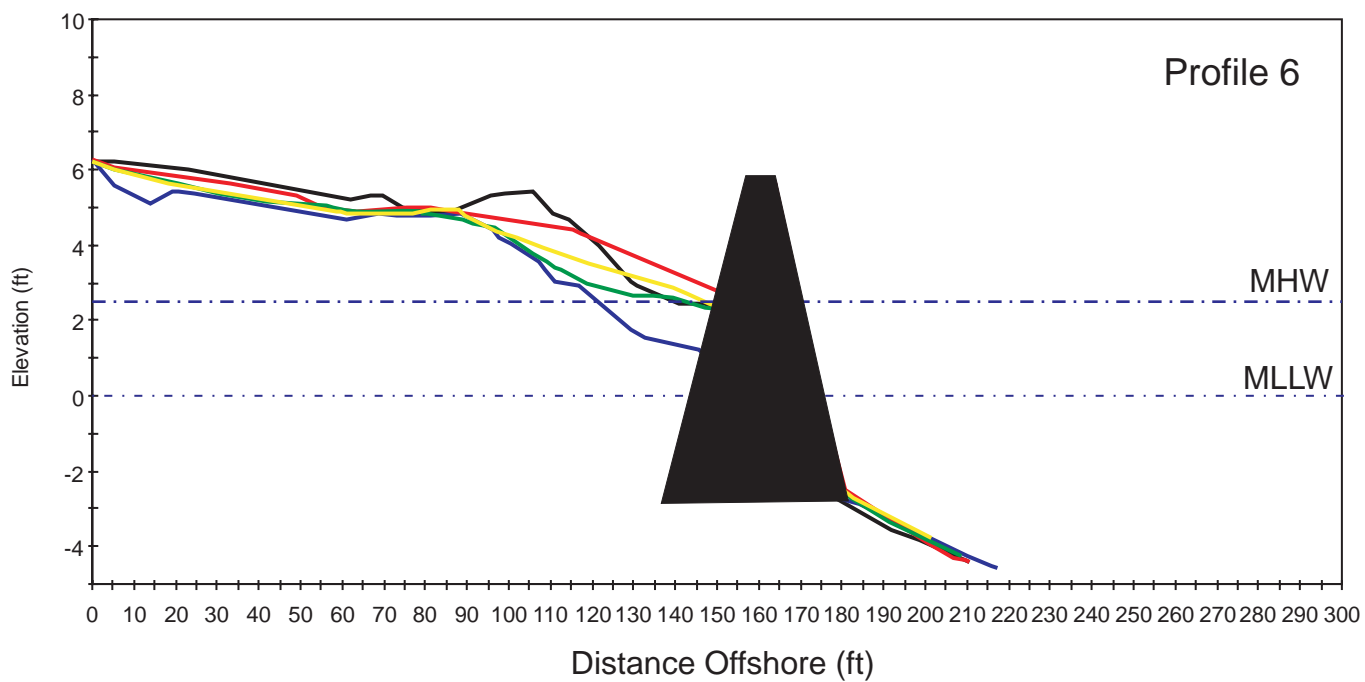


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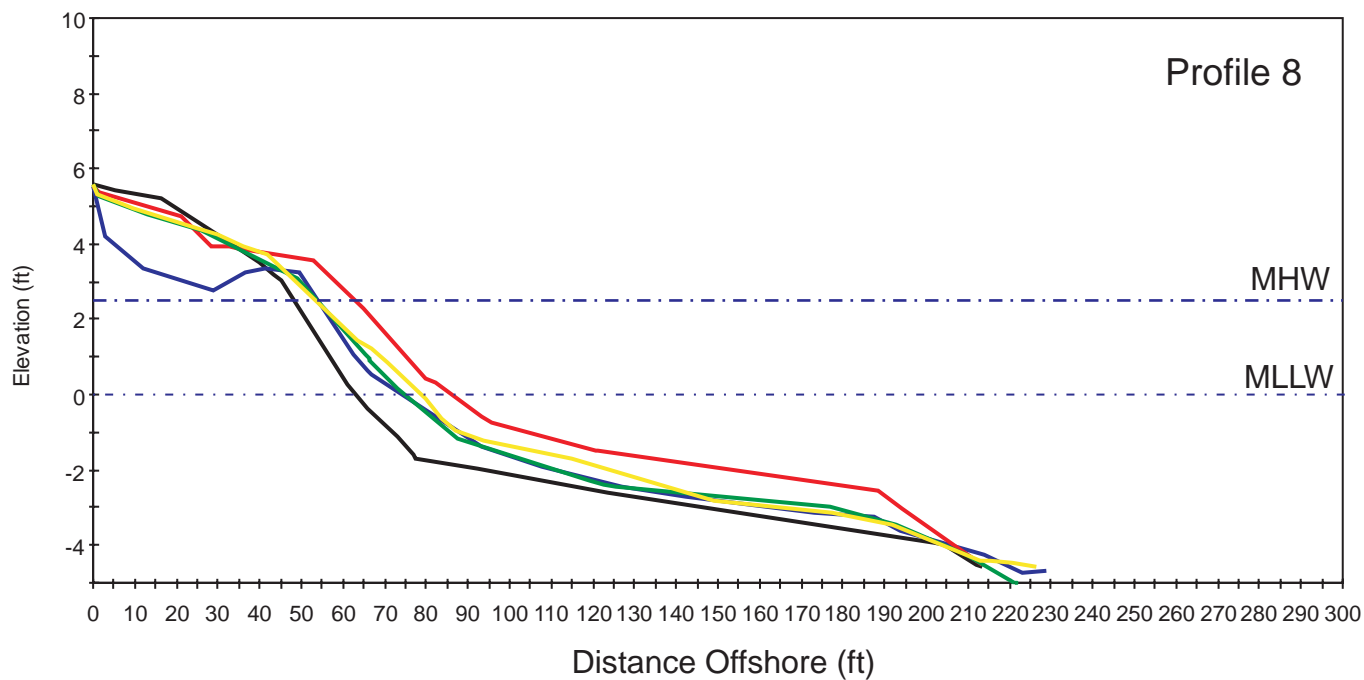
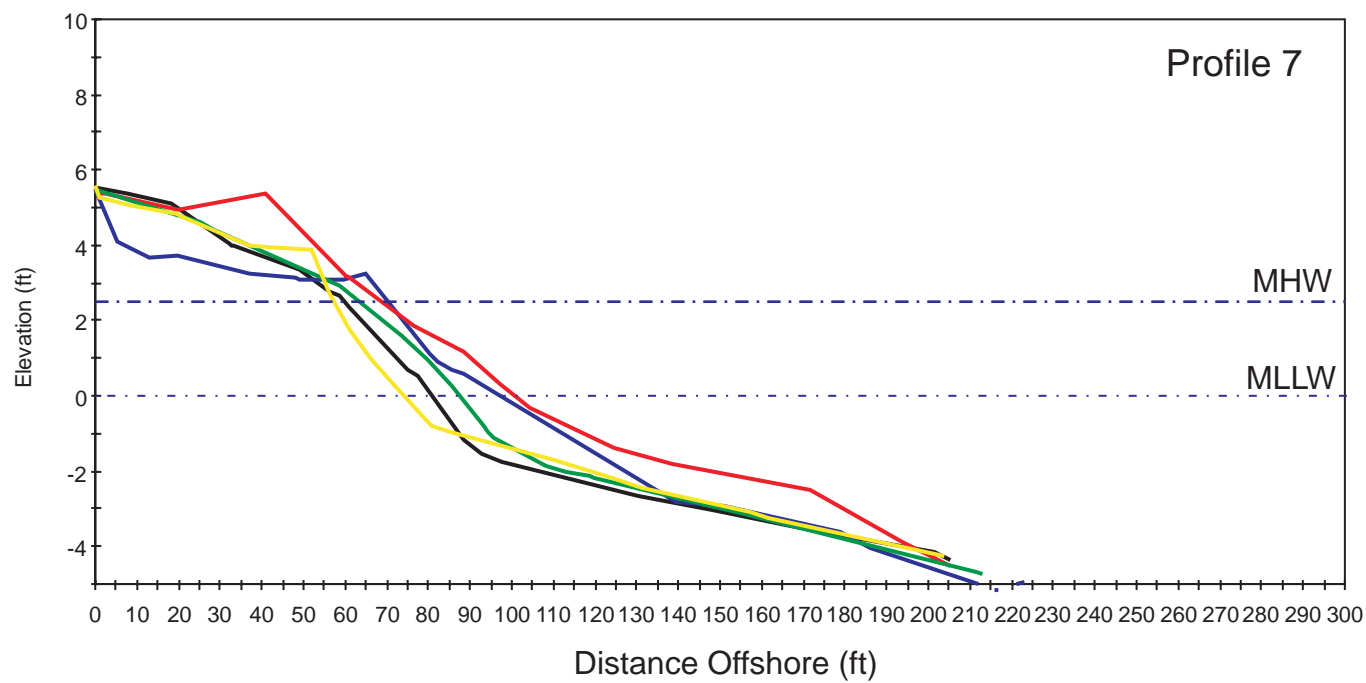




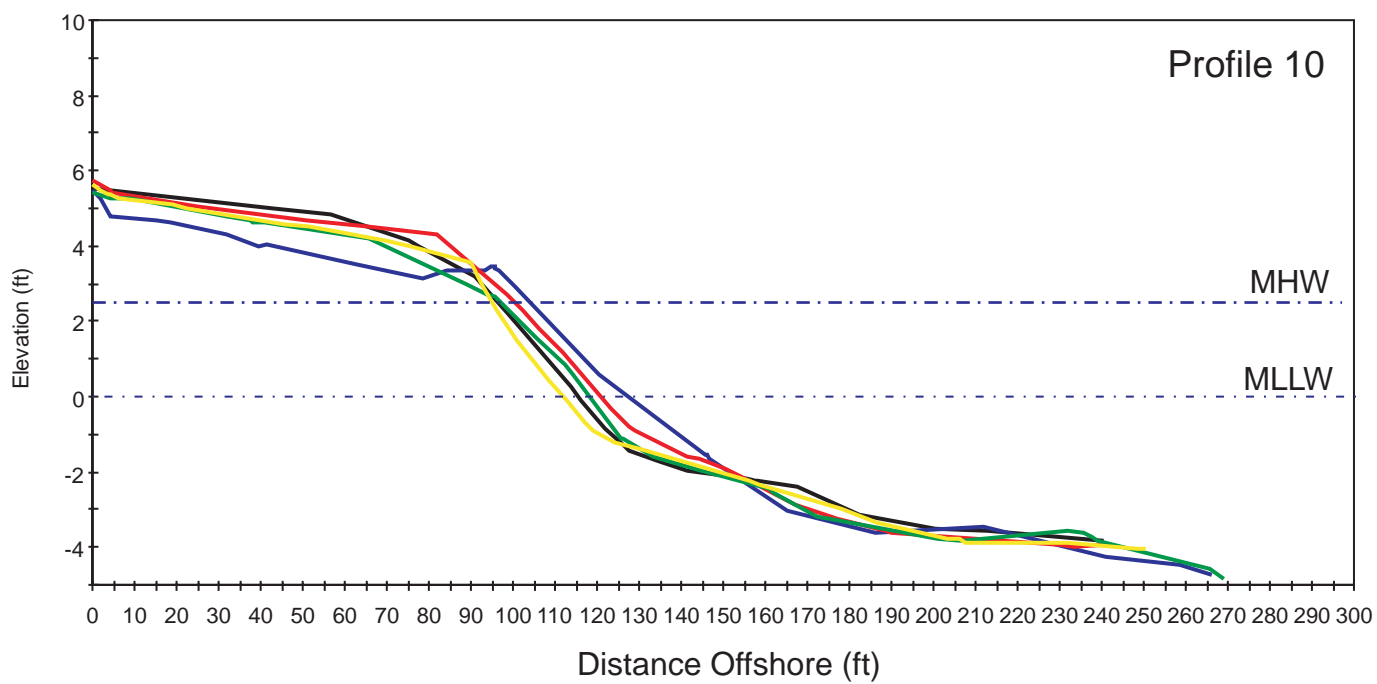
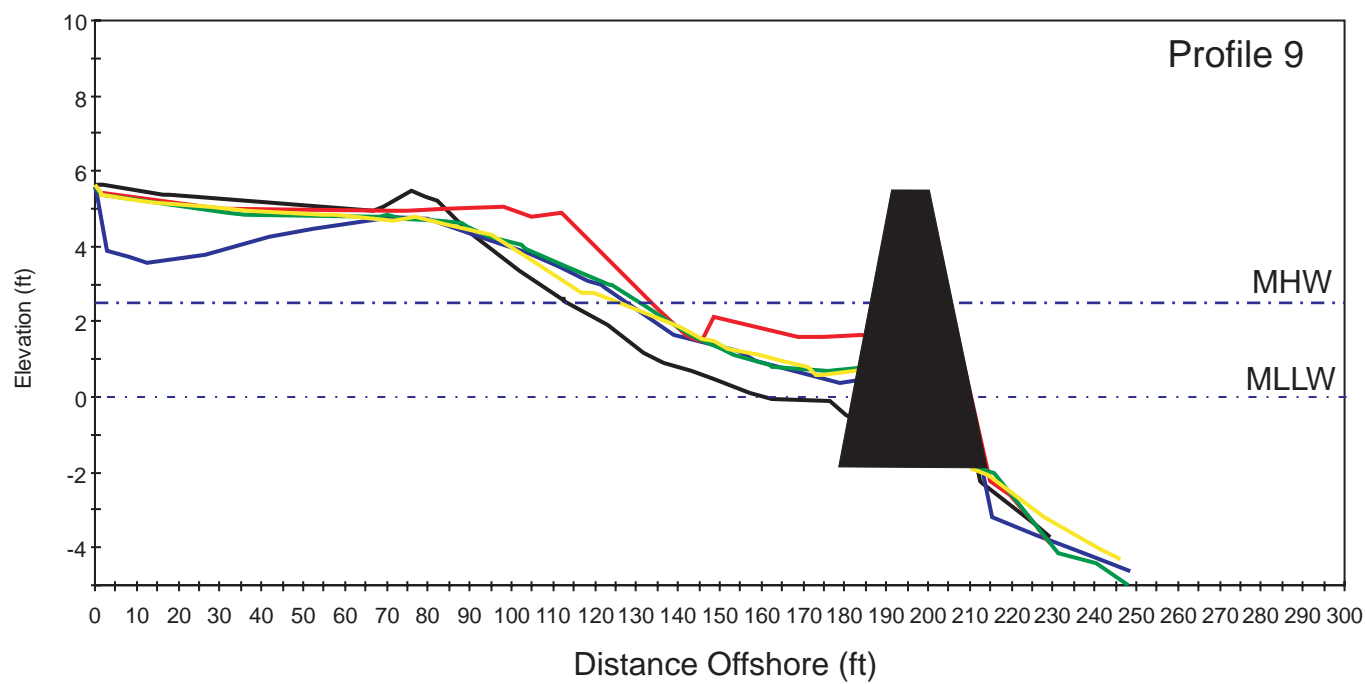
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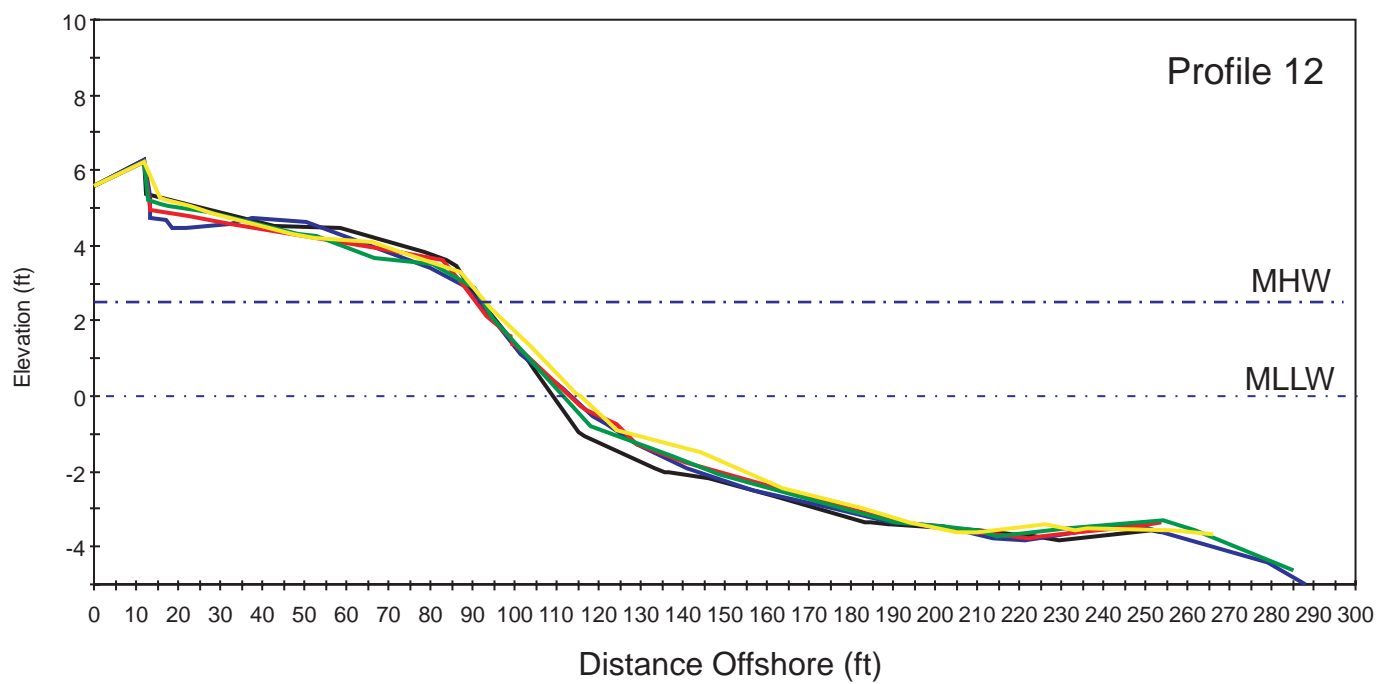
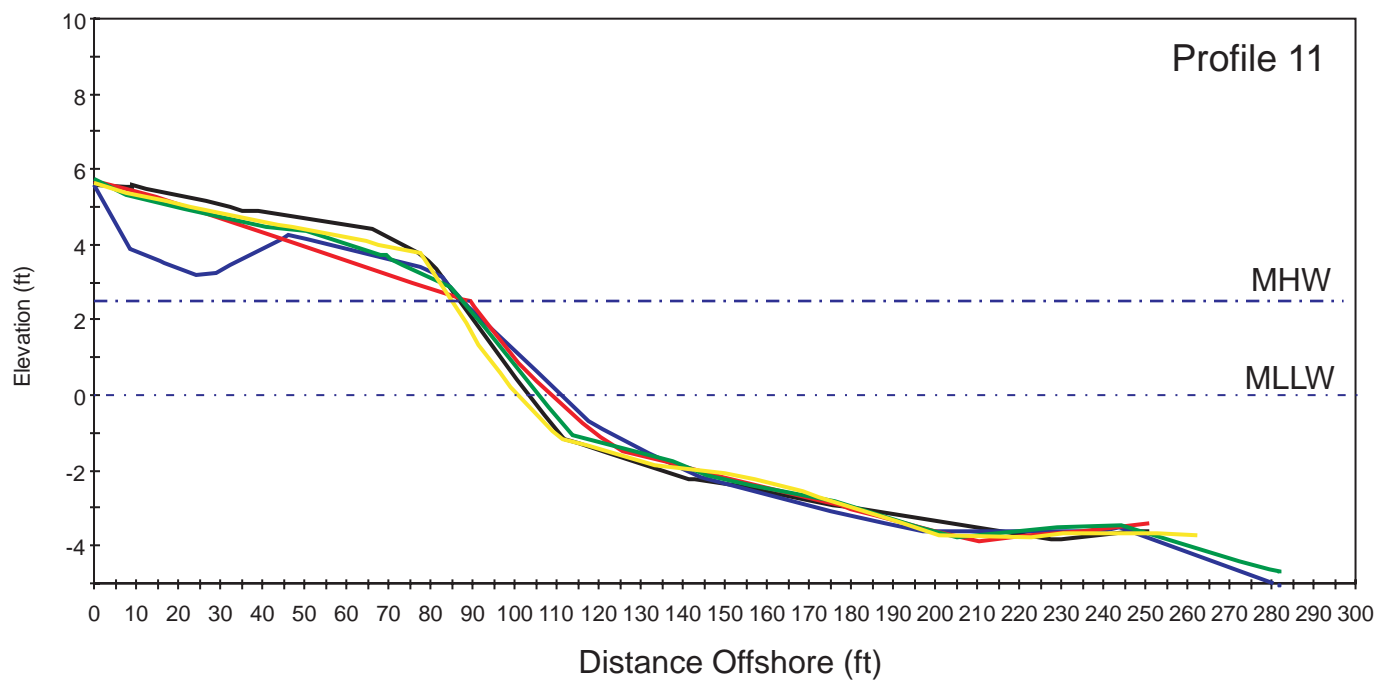
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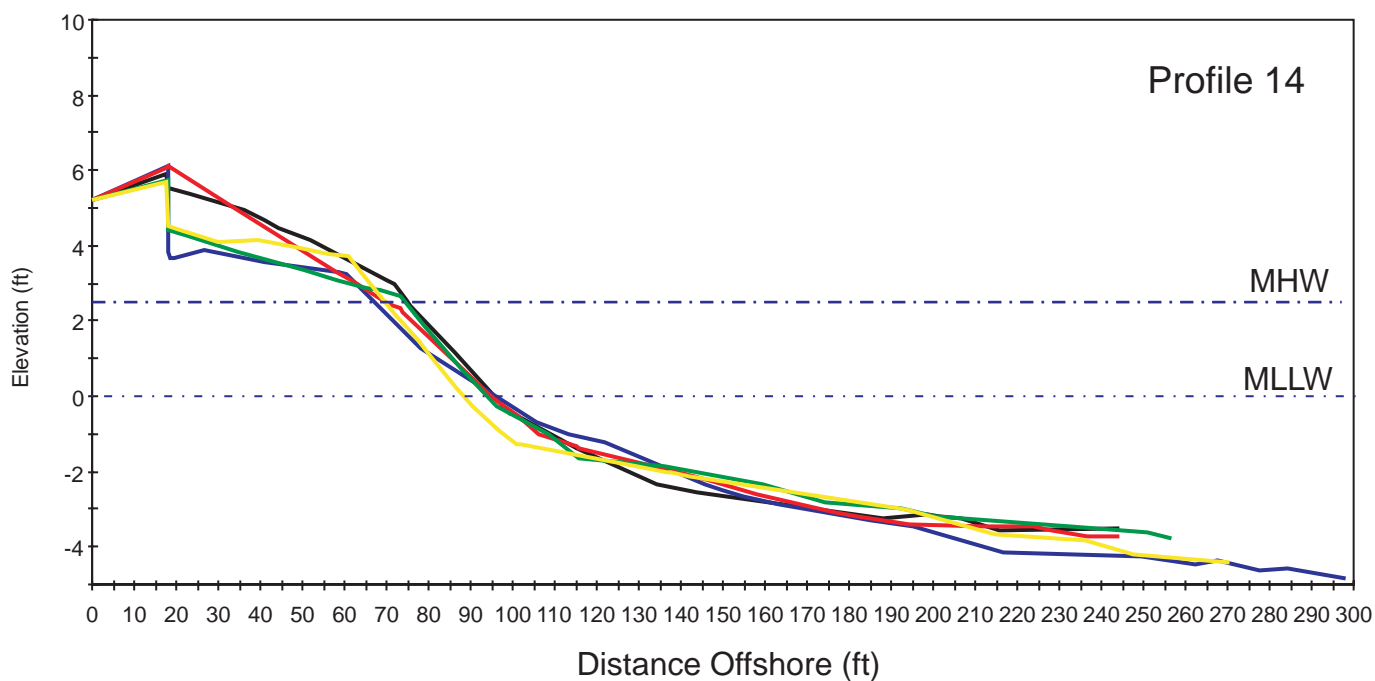
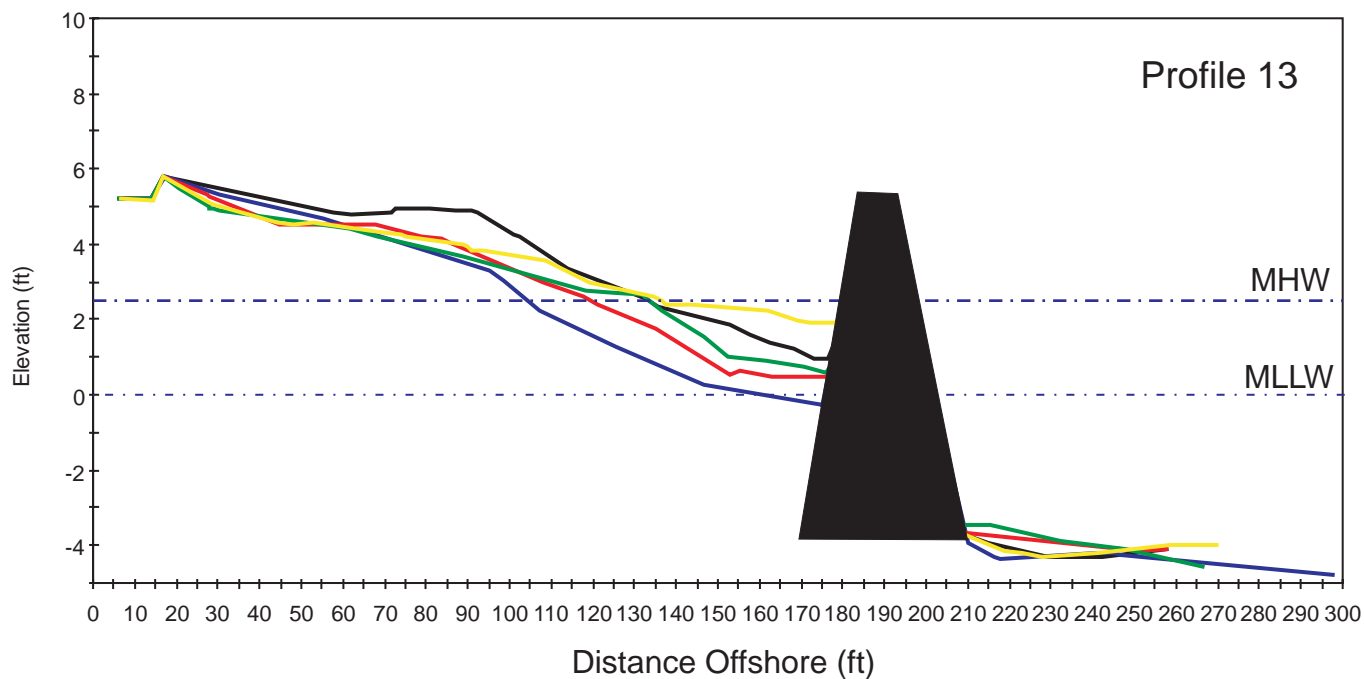
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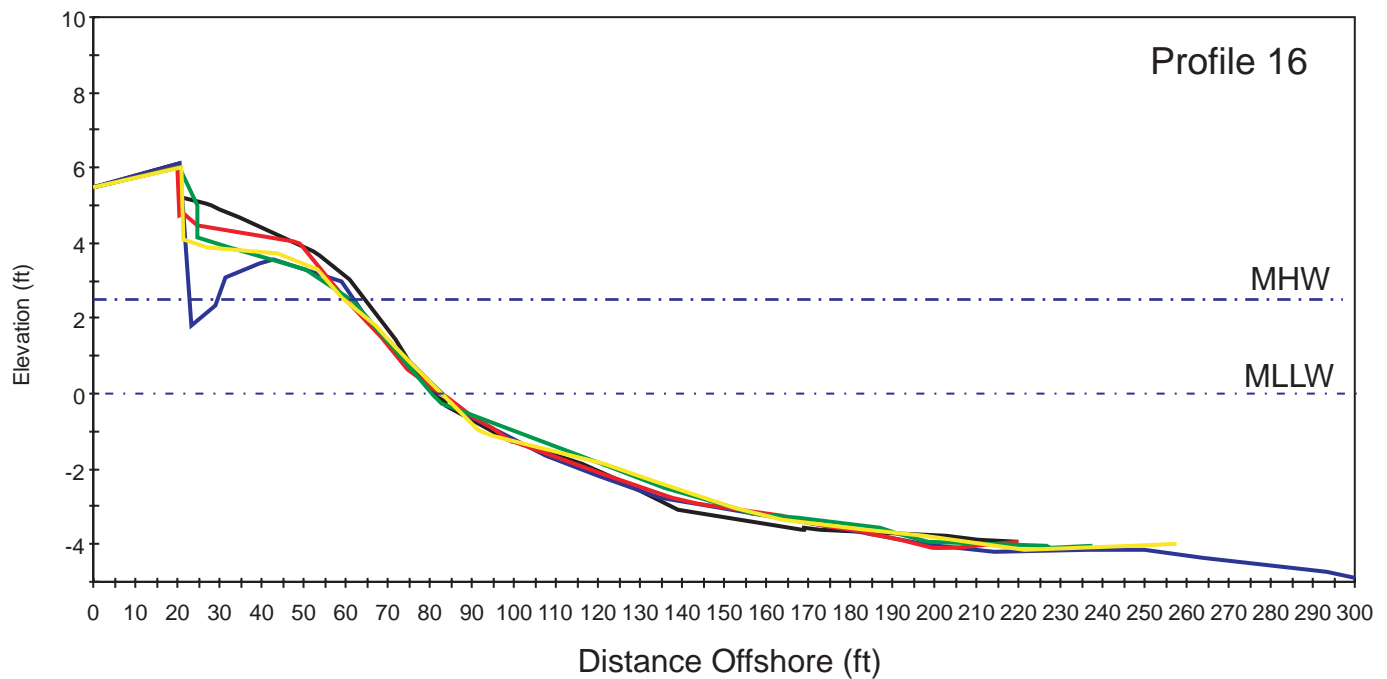
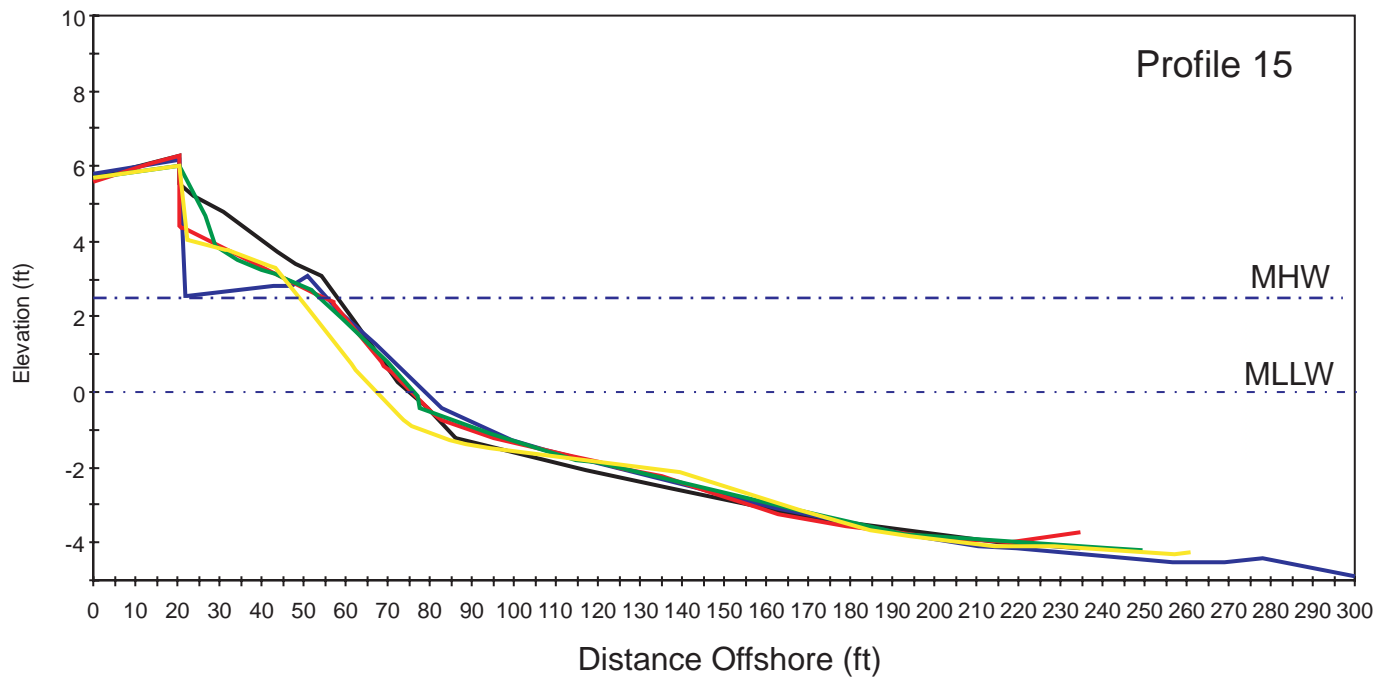
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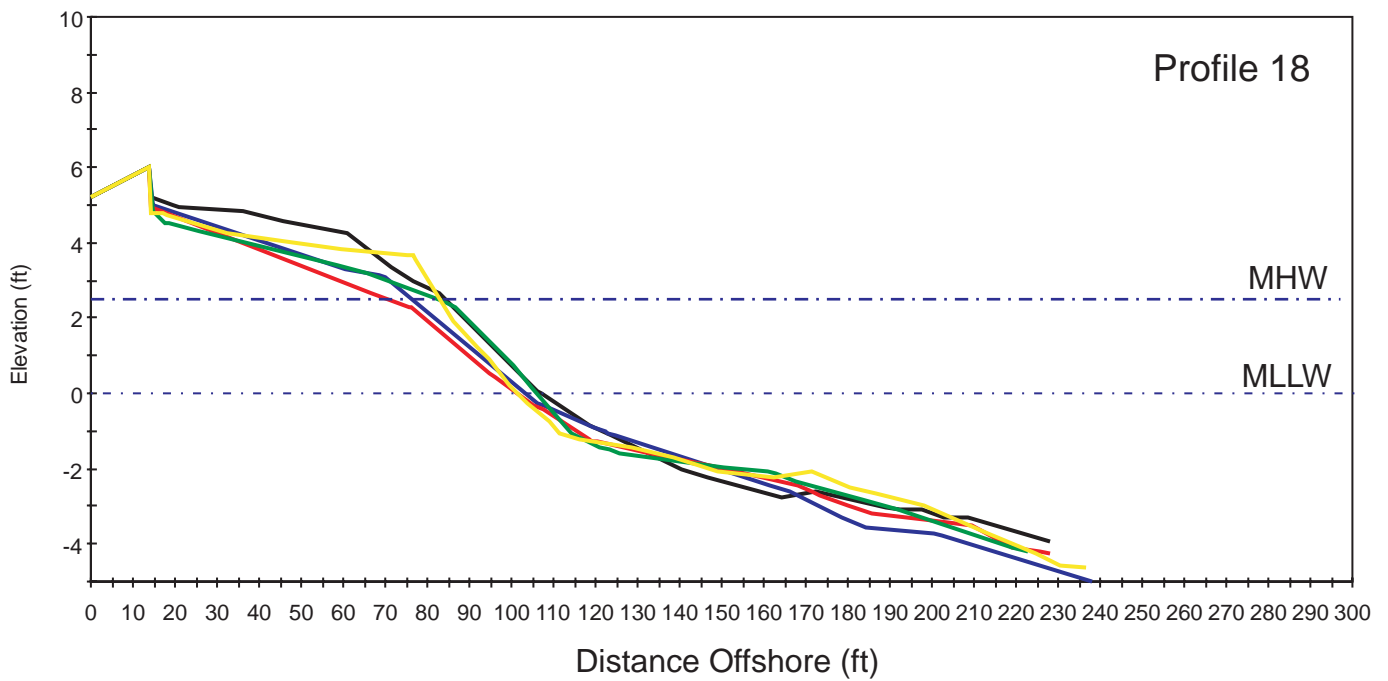
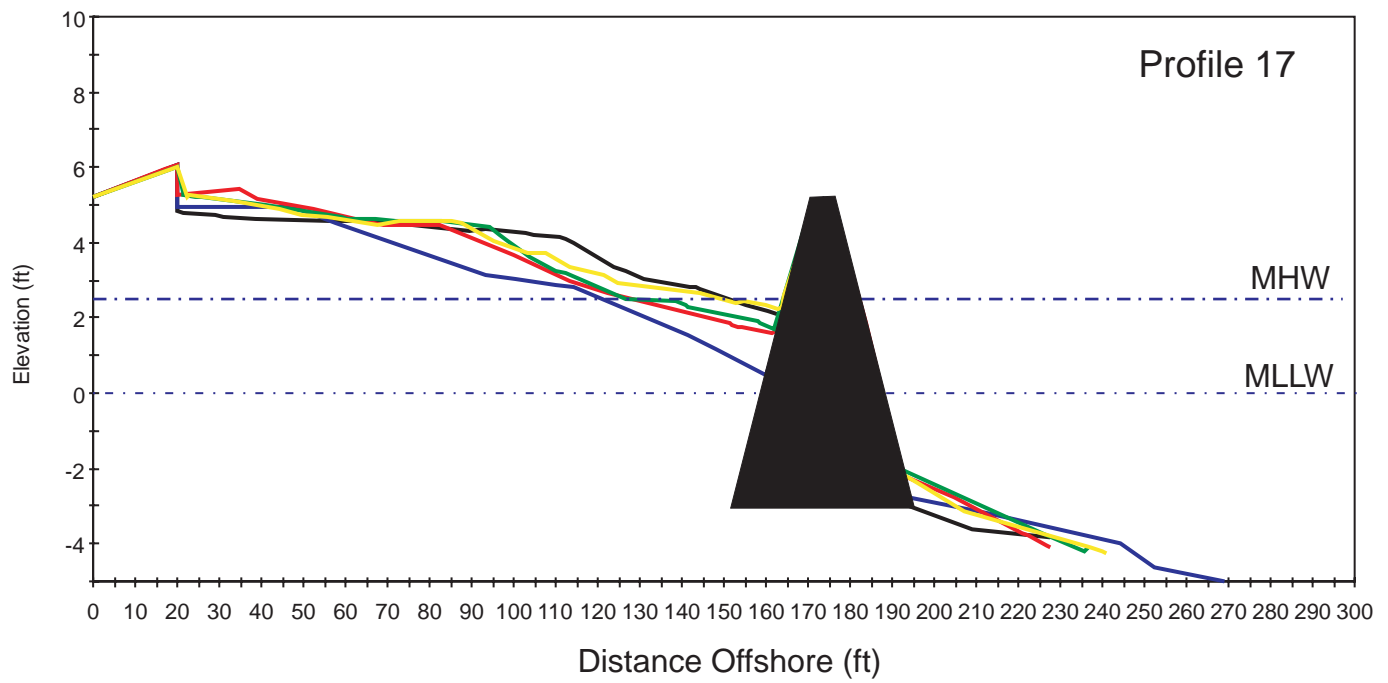
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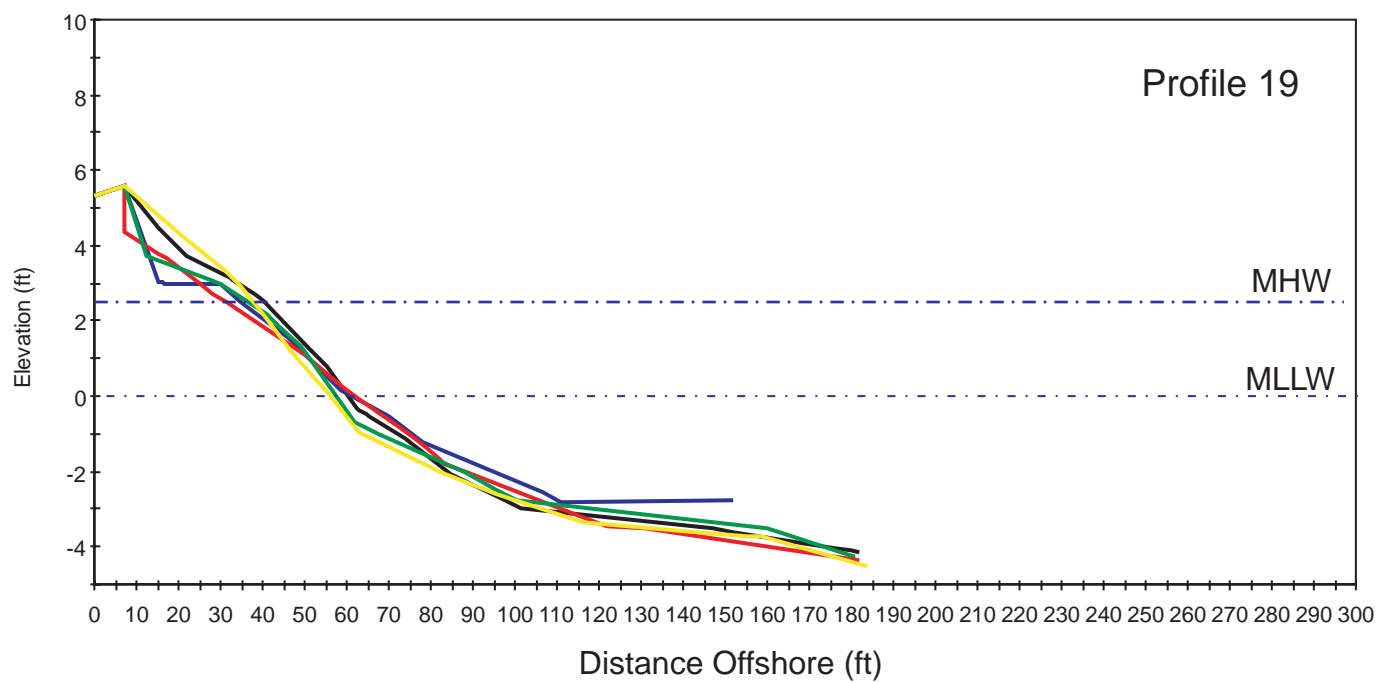
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